THE INFLUENCE OF TASK VARIABLES ON PSYCHOMOTOR PERFORMANCE VARIABILITY

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SUMMARY

There have been many studies of psychomotor performance which use mean reaction time as a dependent measure. Very few studies have been performed which consider variability as the dependent measure. The purpose of the study was to determine the effects of task variables on variability as a dependent measure.

Investigation of the literature revealed the approaches taken on the relatively few studies of variability. The literature also revealed that variables that seemed to affect variability were those of attention, practice and fatigue. These factors provided a basis for the experimental design used in this research.

The type of task used in this experiment was a Fitts' psychomotor task in which parameters of movement amplitude and target width were varied. This type of task was used because of the extensive amount of experiments with this task to successfully predict mean performance and little work performed relating this type of task to variability. A secondary task was used which consisted of three levels. The levels were a pause control task, a mental task, and a motor task.

The statistical measures used to analyze the data were the mean, standard deviation and coefficient of variation.

The results show that the secondary task performed with the Fitts' task had little effect on the variability of performance. Also shown was that the precision of movement had the greatest effect on

performance variability when variability was measured by the coefficient of variation. Variability was also shown to be related to quantitative models of performance but in a less precise manner than to mean performance.

CHAPTER I

INTRODUCTION

Definition of the Problem

Variability of psychomotor performance is an important area that has received a minimum amount of attention. It is an area that can have important consequences in work performance. Variability has been shown to be important in the following areas:

1. Quality of work is often related to variations in performance time.

2. Variability in performance can be used as a more sensitive measure than mean task time in studying certain variables such as fatigue and the effects of alcohol and drugs on performance.

3. Variability in performance can be related to accidents.

4. Variability in performance times has an impact on the effective balancing of assembly times and scheduling of work.

Industrial Engineers and psychologists have developed many systems to predict mean performance on a variety of tasks. However, none of the available systems can reliably predict variability in performance times.

In most situations the impact of task variables; such as movement distance and movement precision, on mean performance time is well understood. The impact of these variables on performance time variability is generally not known. An important contribution to the study of psychomotor performance is to examine the effect of task variables on variability as a dependent measure.

Objective

The objective of this study is to investigate the task variables that affect variability of psychomotor performance. The task variables examined were movement amplitude, target width and the complexity of a secondary task.

Scope

Variability was measured in two ways. One measure was the standard deviation of the movement time and the other measure was the coefficient of variation which is the standard deviation divided by the mean. The data were collected on four subjects performing a psychomotor task under controlled laboratory conditions.

CHAPTER II

LITERATURE REVIEW

General

One of the first investigations of variability in human performance was by Dodge (1924). Several major points concerning emphasis in experimental design and statistical analysis in this study are still true today. One important point is that in the literature of psychomotor performance there is too much emphasis on central value parameters such as the mean. The author states that psychology is one area of study were attention should be paid to the modeling of variant processes instead of merely finding constants.

An extensive literature review was performed on variability emphasizing intra-individual response variability by Fiske and Rice (1955). Fiske and Rice point out the fact that the problem of intra-individual variability has not been systematically conceptualized. Intra-individual variability is defined as the difference between two responses of an individual at two points in time under the following conditions: (a) the individual is exposed each time to the same stimulus or to objectively indistinguishable stimuli; (b) the total situation in which the responses are made is the same on both occasions.

Fiske and Rice state another important assumption. The assumption is that intra-individual response variability is not random; it is a lawful phenomenon. The variability of one individual's responses to one stimulus is determined by more or less enduring factors within the individual.

Studies by Allport and Vernon (1933), Glanzer (1953) and Sanders (1952) discuss research on many topics related to variability, but do not discuss psychomotor tasks directly.

Psychometric Aspects of Variability

Fiske and Rice (1955) state that the phenomena of variability are usually viewed negatively. Efforts are usually made to minimize the extent of intra-individual variability. This minimization is why one seeks high test-retest reliability and eliminates stimulus items to which inconsistent responses are made. Guttman (1945) points to three kinds of psychometric variation: persons, items, and trials. However Gutman and others recognize these concepts without solving the practical problems involved with their measurement. Cox (1936) obtained substantial negative correlations between variability from day to day and initial ability on a motor task. The relation between variability and improvement varied from task to task.

Given a series of repeated measurements for the same individual, several measures of their variability are available and have been used: the standard deviation, the average deviation, and the range. Measures of profile similarity can frequently be used as measures of variability. An example is "D" which is the squared difference between paired responses, as discussed by Cronbach and Glaser (1953).

Correlation coefficients may also be appropriate measures in some instances.

Day to day variations occur even when external conditions are well controlled. Woodrow (1932) has suggested the concept of "quotidian variability," which may be used to describe individuals and also to check on the stability of internal conditions during an experiment. This investigator recommends a ratio where the nuemrator is the standard deviation of the daily means and the denominator is the average of the standard deviations for each day divided by the square root of the number of trials per day. This formula measures variation from one day to the next in terms of variation within one occasion.

Another method of studying sequence of responses is spectral analysis, which yields a profile of the relative contributions to the total variance (or oscillations of performance) of each of the possible component waves. Abelson (1953) demonstrated its use on a perceptual-motor-task and compared it to a conventional measure, variance. The correlation between the two measures was only .08 indicating independence of the two measures even though the data is the same.

Consistency of Variability Over Time

Variability involves the difference between two responses. A measure of variability is usually computed from several such differences between paired responses or from the several deviations from the central tendency of a series of responses. The several responses may be made on one occasion, or two occasions, or on several occasions.

Questions arise such as are measures of variability consistent? Does variability within one occasion show internal consistency? Is variability on one occasion related to variability on another? Are variability measures based on comparisons of responses on two or more occasions internally consistent? Do variability measures show systematic trends over time? These questions are generally unresolved in the literature.

To increase the stability of measures of variability Fryer (1937) discarded the first and the last ten trials per day. In the analysis of his data the individual standard deviations for the second, third and fourth days showed intercorrelations of .48 to .82 with each other but not with the standard deviations of the first day.

Psychophysics would seem to be an excellent source of data on variability, since many of its methods involve repetitions of the same stimulus. Most of the research in this area is normative -- it is concerned with general functions and not individuals. For example, Guiford (1936) neglects differences in intra-individual variability.

Accuracy of Performance and Variability

Some of the first work on variability concerned itself with performance accuracy. Thorndike (1923) studied the distribution of the individuals deviation from his own average. Variability in hand-aim steadiness within one session was studied by Lowel (1941). Three measures were used: average deviation, relative variability (average deviation divided by the mean) and sum of successive differences between pairs of trials. For all three measures, substantial correlations were obtained between scores for two sessions a month apart. The values ranged from .49 to .74 with those for relative variability being the lowest.

Variability and Other Variables in Early Literature

In human subjects increasing motivation may increase variability in performance. Deese and Lazarus (1952) obtained greater variability of performance on a Rotary Pursuit Test by making the task more important to the subjects and by enducing failure stress. These factors also increased the intra-individual differences in variability. In another study at Brown University it was found that measuring variability of reaction time for binocular fusion under conditions involving emotional stress may be useful in selecting emotionally stable people.

Criticisms on Early Studies of Variability

Most of the studies relate variability with a single measure. Fiske and Rice (1955) point to the fact that there is no definite evidence on the generality of variability. There are a number of factors that seemingly affect variability. They are factors in the situation, factors in the individual such as physical and personality factors and of course interactions.

Practice and Variability

Grose (1967) performed investigations concerning the question of whether practice decreases the variability of performance. He determined the effects of practice on inter and intra-individual variability of motor performance. The motor tasks used ranged from a minimum amount of movement (finger press), through the movement of a limb (the arm), to an entire body movement which involved a foot forward progression. The subject's task in all three conditions was to regulate or time the response so that its completion would coincidence with a moving object in line with a fixed index pointer. Grose's analysis leads to the following conclusion: When the variance of the scores is split into inter-individual and intra-individual components, it is found that practice does not cause individuals to become either more alike or less alike, but it does make the individual less variable. Practice failed to cause any change in the variability among subjects, but practice did cause the variability within subjects to decrease, 14 percent in finger response and 27 percent in the arm and whole body response.

Grose makes the same point as Fiske and Rice (1955). There is definitely a lack of quantitative evidence on the factorial structure of variability and a need for further investigation of this important aspect of performance.

Lersten (1968) also examines the effects of practice on inter- and intra-individual variability. He focused on the determination of these variances under two main conditions: (1) during a period when a large amount of learning is taking place, and (2) late in practice, where learning has essentially plateaued. The subjects in this experiment were tested on a Hoerth type pursuit rotor. Lersten concluded that inter-individual as well as intra-individual variability tend to parallel the initial increases in performance and then stabilize in later practice.

Stelmach (1969) examined individual differences and intra-individual variability in motor performance under continuous practice conditions. The task used in the experiment required the subject to maintain whole body balance on a device called a stabliometer. The results were that Inter-Individual variability showed a slight increase during practice and intra-individual variability remained relatively unaffected by massed practice.

Variability and Complexity of Movements

Norrie (1967) examined variability and related it to movement times for simple and complex movement tasks. Nouie found that inter-individual variability of movement time showed little change with practice on the simple task. However on the complex task inter-individual variability for movement time decreased with practice.

Attention and Variability

Some of the most recent research dealing with variability focuses upon attention and uses variability as a sensitive measure to study this phenomena. Posner (1969) examined the effects of secondary tasks and sensory modality on attention using variability as a dependent measure. Three repetitive movements were studied. These were a blind movement between two stops, a visually guided movement to a line and a blind movement which had to be terminated at a previously learned position. Previous work had shown that the first of the conditions caused no interference with reaction time to a secondary signal presented during the movement, while the other two conditions did interfere with reaction time. In this study subjects either performed the movement task alone, together with a key positioning task or under instruction to think about something else. The variability of movement and pause time was used to score the movement tasks. When the movement was performed alone, variability was least for the blind movement between stops and most for the blind movement with the remembered target. All tasks showed increased variability when performed with the subsidiary key task. The instruction to think about something else increased variability but not significantly. The task component which showed the least influence was the variability of movement distance in the blind task without stops.

Salmoni (1974) examined the variability of the speed of handle-cranking while subjects monitored vision, kinethesis or both modalities. The conclusion was that variability was not greater in the dual modality monitoring condition.

Variability and Work Performance

The above studies relating variability and attention point out the need for examining how task variables affect variability. As eluded to previously, most of the studies in the literature consider variability in performance as something to be controlled. Murrell (1962) was one of the first to recognize the practical consequences of variability. According to Murrell (1974) knowledge of operator variability can be used at least three ways: to determine the quality of an operator's performance, to minimize lost time on production lines and to optimize the speed of a paced task. Useful data on operative variability must be obtained by an automatic method of recording cycle times; such times obtained by a human operator with a stopwatch have the variability of the observer superimposed on the variability of the operator being observed.

Variability of Production Output

Dudley (1958) examined variability in production output for a given operator during the working day. He found variability to be low at the beginning and the end of the working day and relatively stable from midmorning to midafternoon. Klemmer and Lockhead (1962) after studying more than 1000 key punch operators concluded that individual variability was about 6 to 10 percent of the group mean and that variability of the individual is independent of the production level.

Salvendy and Seymour (1973) state that variability in production output during a working day may be due more to ancillory work and operational and personnel delay than to the variability of the human operator. Delays that are mainly operational occur at the start of the working day, just before and after lunch, and toward the end of the working day. These delays result in decreases in production output and increased variability in production output during the day.

Rothe and Nye proposed that incentives to work may be ineffective when the range of intra-individual differences is greater than the range of inter-individual differences (Rothe, 1946, 1947, 1951, 1970; Rothe and Nye, 1958, 1959, 1961). Their studies indicate a unique tool for evaluating the effectiveness of incentive schemes in industry. Simmons (1958) finds the effectiveness of work incentives could also be increased by retraining of less productive workers, which would lead to a decrease in individual differences.

Salvendy and Seymour (1973) conclude that the ratio (1:2,5) between the lowest and highest performers found in the literature does not hold in real world situations when the sample is based on a larger group engaged in different and diversified tasks. Salvendy and Seymour conclude that the variability between efficiency indices for industrial operators performing light manual operations in industry is less attributable to inherent variability in the operator and more to organizational work methods and learning factors.

Paced Work and Variability

According to Murrell (1969) paced work will be influenced by operator variability. The variability about the mean performance time and will not disappear just because an operator is paced by a machine. If a job is paced and the machine is set at a speed equivalent to the mean, on more than half the occasions the operator will complete the task within the time allowed and on the remainder will be forced to work faster to keep up. Murrell (1963) suggests that when no tolerance is permitted by the machine he will "miss" on most of the occasions on which he would take longer on an unpaced condition. Murrell further suggests a model of rigid pacing and has proposed a mathematical model to predict the number of messes at a given machine speed. However, messes can be expensive in industry. It is therefore likely that machine speeds will be set lower than mean speed. Murrell (1963) suggests that output will be substantially reduced below that which is possible when self-paced.

Different operators will have different variabilities. Consequently operators who have a smaller variability are likely to have a smaller number of "messes" than those who have greater variability and their output will be higher.

Conrad (1955) studied variability and performance. The task in his experiment involved the operation of an automatic weighing machine which allowed only a set time for the operator to insert material. If the task was not completed by the end of the fixed time the operator had to wait for the next cycle. Conrad gives an example of two operatives, both of whom had a cycle time of 6 seconds. One of them had a coefficient of variation of .15, the other's was .30. Table 2-1 shows the effect on output of running machines at various speeds.

Variability and Production Lines

Murrell (1974) finds the majority of work on assembly line balancing has assumed that element times for each operation are rigidly fixed. Based on this assumption one may go to extreme lengths to optimize the balance. In the determination of line output some average performance is usually used. Opinions vary as to whether this should be incentive pace or the average shop or line performance. From a production line efficiency view, the main consideration is not average

Table 2-1. Changes in Packing Time (sec) and its Coefficient of Variation over the Working Day (after Conrad and Heller, 1953)

Mean Packing Time					Coefficient of Variation			
Operator	Period		Differences		Period		Differences	
R	I	4	4-I	%	I	4	4-I	%
A	7.39	7.34	-.05	-.68	.177	.207	+.030	+14.5
B	7.20	7.29	+.09	+1.25	.247	.315	+.068	+21.5
C	6.85	6.84	-.01	-.15	.211	.222	+.011	+5.0
D	7.43	8.26	+.83	+11.2	.146	.184	+.038	+21.0
E	7.71	7.59	-.12	-1.56	.156	.201	+.045	+22.5

performance over the working period but the performance per cycle. This performance will vary because of the following factors:

(1) Each individual operator varies his or her working pace throughout the working period.

(2) No two operators work at the same pace throughout the working period.

Operator variability is often put forward as the reason why line balancing techniques are not used more extensively. However, Van Beek (1961, 1964) have shown that line balancing techniques combined with heuristic approaches do seem to work. Van Beek (1961) investigated operator variability in television set production with 100 operators working next to each other on assembly lines. Two classes of operator variability were isolated and investigated. These classes were the following: (1) System losses - due to individual operator variability of each work station and 21 balancing losses - due to waiting time caused by differences in average operation time between work stations. The total average waiting time covering balancing and system losses on the test line was 19 percent of the operation time. This is 19 percent loss of output. Individual operator variability was approximately normally distributed with 99 percent of times falling between 55.7 and 124.7 seconds with an average of approximately 90 seconds.

An investigation into system losses was conducted to determine ways in which this variation in time could be accommodated on the line. The data showed that there was an average of 10 percent variation between each work place. The study of balancing losses showed that the variation of standard times among the work stations was 3.5 percent and the variation of the average operator speed was 9.6 percent. The balancing loss on the average must be higher on a large line taken on a small one, since the loss is controlled by the extremes in work station times.

Buffer Stocks

Emperical methods for line balancing have included in the design of manufacturing facilities some form of buffer stocks to attempt to smooth operator variability and other system defects. Van Beek has suggested this method by way of a very small buffer stock on the line itself to reduce system losses. He also suggests a buffer stock stored in racks alongside the conveyor and between each group. This buffer is to some extent to correct for operator variability but mainly to counter waiting time due to lack of materials. Operator variability is a source of inefficiency in any production line and it is worthy of investigation. Unfortunately little published work is available.

Variability and Mathematical Models of Psychomotor Performance

Sternberg (1969) points out the importance of variability in performance and mathematical modeling of psychomotor performance. Steinberg found experimental evidence in which changes in the variance of performance were opposite to changes in the mean. Sternberg's conclusion fits a model developed by Falmage (1965). This model, unlike other models, can account for changes in variance.

Quantitative Models of Human Performance

A large amount of research in perceptual-motor skills concerns the understanding of skill acquisition and performance of voluntary movements. An important class is simple positioning movements (target aiming movements) with high speed accuracy requirements. The first quantitative relationship between these variables was formulated by Fitts (1954) as:

$$\text{I.D.} = \log_2$$

where: ID = Index of Difficulty

A = Amplitude of movement

w = width of target

Fitts found a linear relationship between Index of Difficulty and mean performance time. Fitts' law has been used to predict the time for a variety of motor responses (e.g., Drury, 1975; Langolf, 1973). Fitts' law has proven to be a good quantitative model of performance, but it has only been used to predict mean performance time. The variability of psychomotor performance has not been examined with this model.

Conclusions

In recapitulation variability is a statistical concept which has received little attention in the massive amount of human performance research. Variability can illustrate performance changes such as performance decrements induced by factors such as fatigue even though central tendency measures may not change. The major variables which have been related to variability are those of attention, fatigue, and practice. In terms of task variables little has been done to directly relate these variables to variability. The tasks used have been identification tasks or motor tasks such as the pursuit rotor. Quantitative models of human performance such as the Fitts' model have been developed psychomotor performance but variability has not been included in these models.

CHAPTER III

METHODS AND PROCEDURES

General

The variables chosen for examination in this experiment were amplitude of movement, target width and complexity of a secondary task. The Fitts' psychomotor task was used to integrate the first two variables. By varying target widths and amplitudes of movement an index of difficulty can be obtained and related to the variability of psychomotor performance and to the levels of secondary task complexity.

The response of the subject was to hit a target with the index finger of the right hand and then hit a second target (see Figure 3-1) After hitting the second target the subject then performed the secondary task located four inches to the left of the second target. The secondary task was performed during a five second interval. When the subjects completed the secondary task they placed their hand on a button which served as a starting point for the next cycle. This starting button was located 2 inches to the left of the secondary task location. At this point the subjects waited for a red light which was located between the two Fitts' targets. This light signaled the start of the next cycle.

Equipment

The Fitt's task apparatus consisted of used (target) and white (error) plexiglas plates mounted in a wooden box 6 inches long and 4 inches wide (see Figure 3-1). The axes of the plates were perpendicular to the line of movement between them. The plates were mounted with pins so the plates could be changed to obtain different target widths. Under the plates were micro-switches, which were connected to a Hewlett-Packard electronic timer, Model 5300 A. Under the error plates other micro-switches were placed which were connected to counters which recorded errors. The circuits were designed so that when the subjects lifted their hand after hitting the first target the timer was started. The timer was stopped when the subjects initially pressed the second target. The timing and error circuits are shown in Appendix A.

The subjects were seated at a table which contained the targets, secondary task area, and starting button. The red signal light faced the subject and was connected to a switch activated by the experimenter.

Variables

The task presented to the subject varied in terms of difficulty. The difficulty in the Fitts' task was varied by manipulating target width and distance between the targets. The difficulty of the secondary task performed with the Fitts' task was set at three levels: a pause task, a motor task and a mental task.

Target Size

Four levels of target size were investigated. The levels were .75 inches, 1.0 inches, 1.5 inches, and 2.0 inches. The red target plates were cut to these widths. The white error plates were designed so that the total width of the targets plus the error plates was 4 inches for each target set.

Movement Amplitude

Four levels of movement amplitude were investigated. These levels were 6 inches, 12 inches, 18 inches, and 24 inches between target center lines.

Complexity of the Secondary Task

This variable determines whether a task performed after each movement of the Fitts' task affects the mean and standard deviation of the performance on the Fitts' task. To determine the above, three levels of the secondary task were examined. The first was a control task where the subject paused during the secondary task interval. The second level of complexity was a motor task. In this condition subjects turned a 2 inch radius crank three revolutions during the five-second interval. The third level of the secondary task was a mental task. The subject read and recited three one syllable words during the five-second interval. These words were written on a page three to a line with 50 lines. The subject proceeded down the page one line per cycle: Different sheets were used at each experimental session so that the words would be as random as possible. A typical word list is shown in Appendix B.

Index of Difficulty

This variable is the main independent variable in the experiment. It integrates the variables of target width and amplitude of movement into a difficulty index. As mentioned in the literature review, this index is known as Fitts' law. It is expressed mathematically by the equation:

$$ID = \log_2 \frac{2A}{W}$$

where A = amplitude of movement

W = width of target

According to the levels of amplitude and target widths, 16 ID's were examined under each condition of the secondary task.

Subjects

Four subjects, two male and two female, were used in the experiment. The ages ranged from 18 to 25. The subjects were generally interested in the project, although there were no specific incentives, monetary or otherwise, provided.

Experimental Design

To develop the data required for this analysis, a factorial design was chosen, combining all levels of the variables of width, amplitude and secondary task complexity. This design involved 48 cells or unique combinations of these variables. A pilot study revealed that a series of practice cycles were necessary in each cell in the design. Learning curves from the pilot studies showed that after about 40 cycles learning effects leveled off. It was decided to use 50 practice cycles before each cell in the design so that learning would be minimized. The subject performed 50 cycles, rested for two minutes, and then performed the task until 50 errorless cycles were recorded. The dependent measure of movement time was only analyzed on this second set of data. The 48 conditions were presented to each subject in a random sequence.

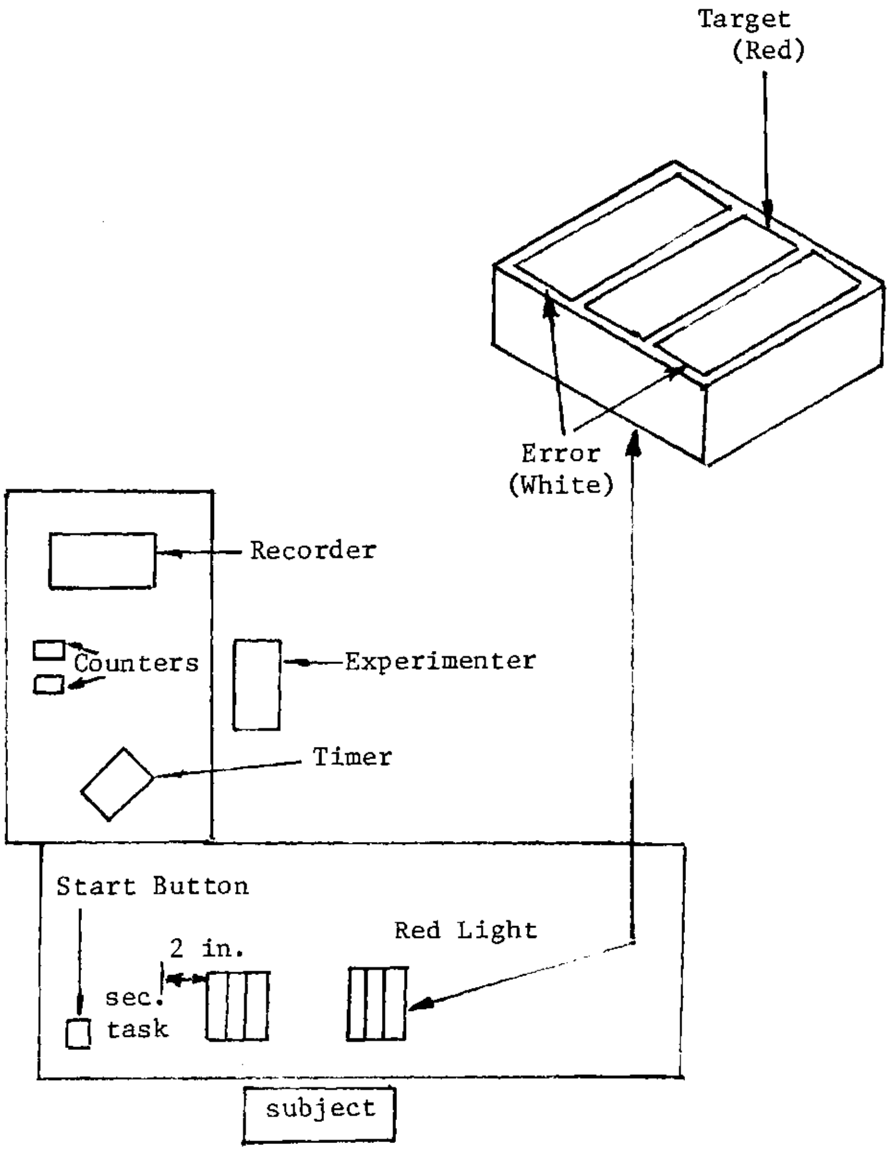


Figure 3-1. Plan View Diagram of Experimental Equipment Arrangement.

Experimental Procedure

In order to facilitate scheduling and to minimize both fatigue and learning, the subjects participated in 6 two-hour periods with one period done per day. The practice trials were performed followed by a two minute rest period. The subject then performed 50 cycles to complete the data for each experimental cell. Each subject rested for five minutes after each cell was completed so fatigue would be minimized and so that the plates could be changed for the next condition.

Data Analysis Procedures

The data was analyzed by subject using an analysis of variance. This was accomplished by the psychometric computer program MANOVA developed at the University of North Carolina. This program also provided means and standard deviations on each cell in the experiment.

Next analysis of variance was performed on the means, standard deviations, and coefficients of variation calculated for each subject's performance in each cell in the experiment.

The second part of the analysis was based on Fitts' law as a model of performance. The means and standard deviations were averaged across the four subjects in each cell in the design. An index of difficulty was calculated for the different widths and amplitudes. The dependent measure of mean time, standard deviation and coefficient of variation averaged across subjects were then plotted versus index of difficulty. Least squares linear regression models were then fit to the data to test the adequacy of Fitts' law as a model. Regression lines were then fit to each subject's data using Fitts' law as a model. The slopes and intercepts of these regression lines were then tested using ANOVA to determine the effect of secondary task condition on Fitts' law.

CHAPTER IV

EXPERIMENTAL RESULTS

The analysis of variance for each subject for overall significance of variables is shown in Table 4-1. The model for this analysis of variance is as follows:

$$MT_{jKLM} = U + w_j + A_K + SE_L + e_m$$

where MT_{jKLM} = movement time

w_j = width of target

A_K = amplitude of movement

SE_L = secondary task

e_m = error

The table shows that all variables are significant at the .001 level. The means, standard deviations, and coefficients of variation are shown in Appendix C.

After the means, standard deviations, and coefficients of variation were obtained for each subject in each cell an analysis of variance was run on these parameters. The model for this analysis as as follows:

Mean Movement time
or
Standard Deviation of Movement time
or
Coefficient of Variation

$$= u + S_i + w_j + A_K + SE_L + e_m + \left(\begin{matrix}\text{2-Way} \\ \text{Interactions}\end{matrix}\right)$$

where u = grand mean

S_i = subject

w_j = width

A_K = amplitude

SE = secondary task

e_m = error

The results are shown in Tables 4-2 through 4-4. The results of this analysis shows that all main effects were significant at the .001 level for the means and standard deviation except for the secondary task condition. The analysis of the coefficients of variation showed that the effect of amplitude as well as secondary task condition was not significant. The two-way interactions were examined in this model. The only significant interaction was that of secondary task and amplitude of movement for the mean time movement model. Because of the differences in significance for amplitude in analyzing the standard deviations and coefficients of variation, graphs were plotted with amplitude versus standard deviation and amplitude versus coefficient of variation (Figures 4-10 through 4-11). Graphs were also plotted for width versus standard deviation and width versus coefficient of variation (Figures 4-11 through 4-13).

Graphs of the mean movement time averaged across subjects versus index of difficulty are shown in Figures 4-1 through 4-3. Each figure represents a different secondary task complexity level. Linear least squares regression analysis was performed using the data. The slopes, intercepts, and coefficients of determination are shown on the graphs. All regression lines were significant at the .-01 level. The tables are shown in Appendix D.

The graph of the Standard Deviation of movement times averaged across subjects versus index of difficulty are shown in Figures 4-4 through 4-6. The results of the regression performed on this data are also shown in Appendix D. The most significant regressions were for the pause and motor conditions which were significant at .01 level and the mental condition which was significant at the .02 level.

The results of determining the significance of regression for the coefficient of variation is shown in Appendix E. The results indicated no significance at the .05 level. The graphs of coefficient of variation versus index of difficulty are shown in Figures 4-7 through 4-10. The data used for the regression analysis is shown in Table 4-5.

To test the effect of secondary test condition on Fitts' law, regression lines were calculated for the mean time versus ID and standard deviation versus ID for each subject. ANOVA was performed to compare slopes and intercepts of these regression lines. The ANOVA model is as follows:

$$\begin{array}{c}\text{Slope}\\ \text{or}\\ \text{Intercept}\end{array} = u + SE_j + S_j + e_K$$

where u = grand mean

SE_j = secondary task

S_j = subject effect

e_K = error

This analysis is shown in Table 4-6. The only significant result was the difference in slopes for the Fitts' model using mean times. The slopes and intercepts for the other conditions were not significantly different. Graphs of the individual subjects data used in this analysis are shown in Appendix F.

Table 4-1 ANOVA for Each Subject for Overall Significance

Subject	Source of Variation	Sum of Squares	d.f.	Mean Square	F	Sig.
	Residual	1080043068.71	2352	459201.98		
1	Sec. Task	8160303.13	2	4080151.56	8.88	.001
	Width	1424699742.76	3	474899914.25	1034.18	.001
	Amplitude	1155544038.71	3	385181346.23	838.80	.001
	Residual	166488315.14	2352	70785.84		
2	Sec. Task	17183826.56	2	8591913.28	121.37	.001
	Width	1570329886.85	3	523443295.61	7394.74	.001
	Amplitude	557720602.20	3	185906867.40	2626.32	.001
	Residual	373143501.10	2352	158649.44		
3	Sec. Task	40822704.57	2	20411352.28	128.65	.001
	Width	675821216.30	3	225273738.76	1419.94	.001
	Amplitude	1124540220.17	3	374846740.05	2362.73	.001
	Residual	316371802.099	2352	134511.82		
4	Sec. Task	11258821.72	2	5629410.86	41.85	.001
	Width	906135854.13	3	302045284.71	2245.49	.001
	Amplitude	741184329.055	3	247061443.018	1836.72	.001

Table 4-2. Analysis of Variance of u in Each Cell of the Design

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	1.926	11	.175	57.800	.001
Subject	.366	3	.122	40.293	.001
Sectask	.001	2	.001	.214	.808
Width	.896	3	.299	98.651	.001
Amplit	.662	3	.221	72.845	.001
2-Way Interactions	.181	45	.004	1.330	.109
Subject Sectask	.021	6	.004	1.176	.323
Subject Width	.031	9	.003	1.146	.335
Subject Amplit	.024	9	.003	.869	.555
Sectask Width	.020	6	.003	1.090	.372
Sectask Amplit	.043	6	.007	2.387	.032
Width Amplit	.042	9	.005	1.533	.143
Explained	2.107	56	.038	12.422	.001
Residual	.409	135	.003		
Total	2.516	191	.013		

u = .34

Table 4-3. Analysis of Variance of σ in Each Cell of the Design

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Main Effects	.040	11	.004	13.705	.001
Subject	.029	3	.010	36.534	.001
Sectask	.000	2	.000	.044	.957
Width	.005	3	.002	6.642	.001
Amplit	.006	3	.002	7.044	.001
2-Way Interactions	.015	45	.000	1.239	.175
Subject Sectask	.001	6	.000	.380	.891
Subject Width	.004	9	.000	1.627	.114
Subject Amplit	.006	9	.001	2.634	.008
Sectask Width	.001	6	.000	.686	.661
Sectask Amplit	.001	6	.000	.668	.675
Width Amplit	.002	9	.000	.778	.637
Explained	.055	56	.001	3.688	.001
Residual	.036	135	.000		
Total	.091	191	.000		

u = .04

Table 4-4. Analysis of Variance of u/σ in Each Cell in the Design

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.691	11	.063	12.952	.001
Subject	.632	3	.211	43.448	.001
Sectask	.000	2	.000	.002	.998
Width	.053	3	.018	3.615	.015
Amplit	.006	3	.002	.425	.736
2-Way Interactions	.313	45	.007	1.433	.060
Subject Sectask	.008	6	.001	.269	.951
Subject Width	.184	9	.020	4.220	.001
Subject Amplit	.035	9	.004	.805	.612
Sectask Width	.024	6	.004	.817	.558
Sectask Amplit	.035	6	.006	1.210	.305
Width Amplit	.026	9	.003	.607	.789
Explained	1.003	56	.018	3.695	.001
Residual	.654	135	.005		
Total	1.658	191	.009		

u = .13

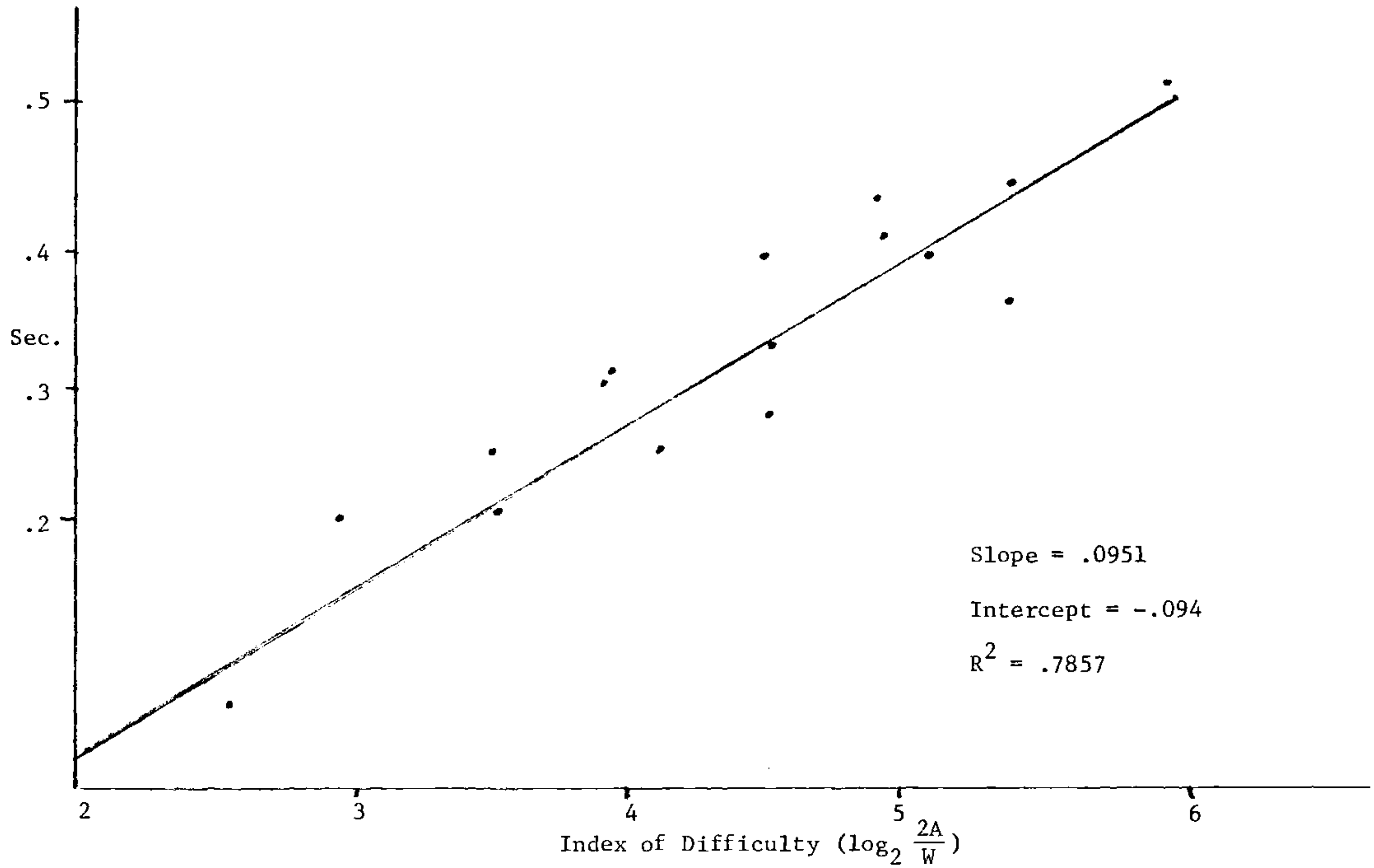


Figure 4-1. Mean Movement Time Averaged Across Subjects vs. Index of Difficulty for Pause Condition.

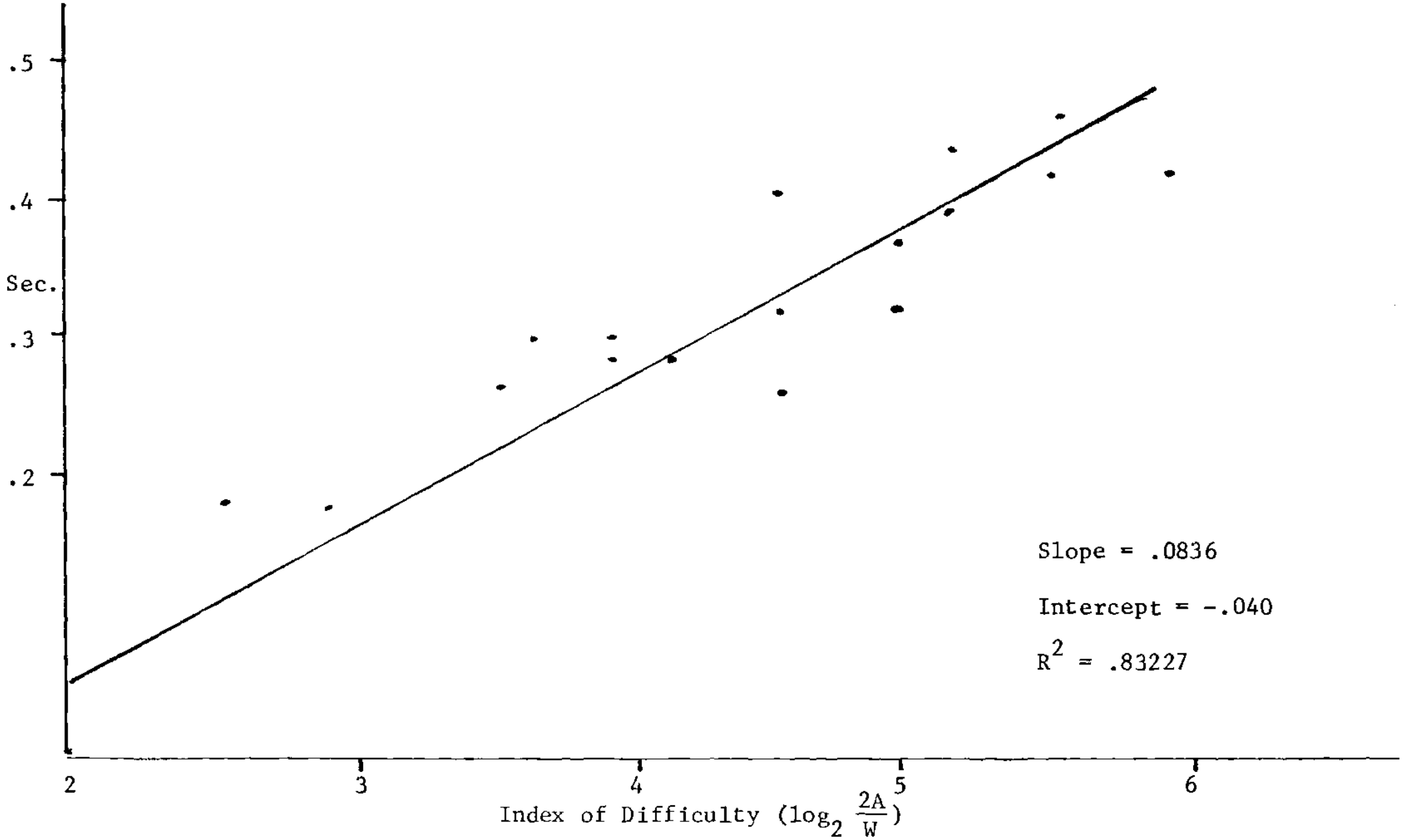


Figure 4-2. Mean Movement Time Averaged Across Subjects vs.
Index of Difficulty for Motor Condition.

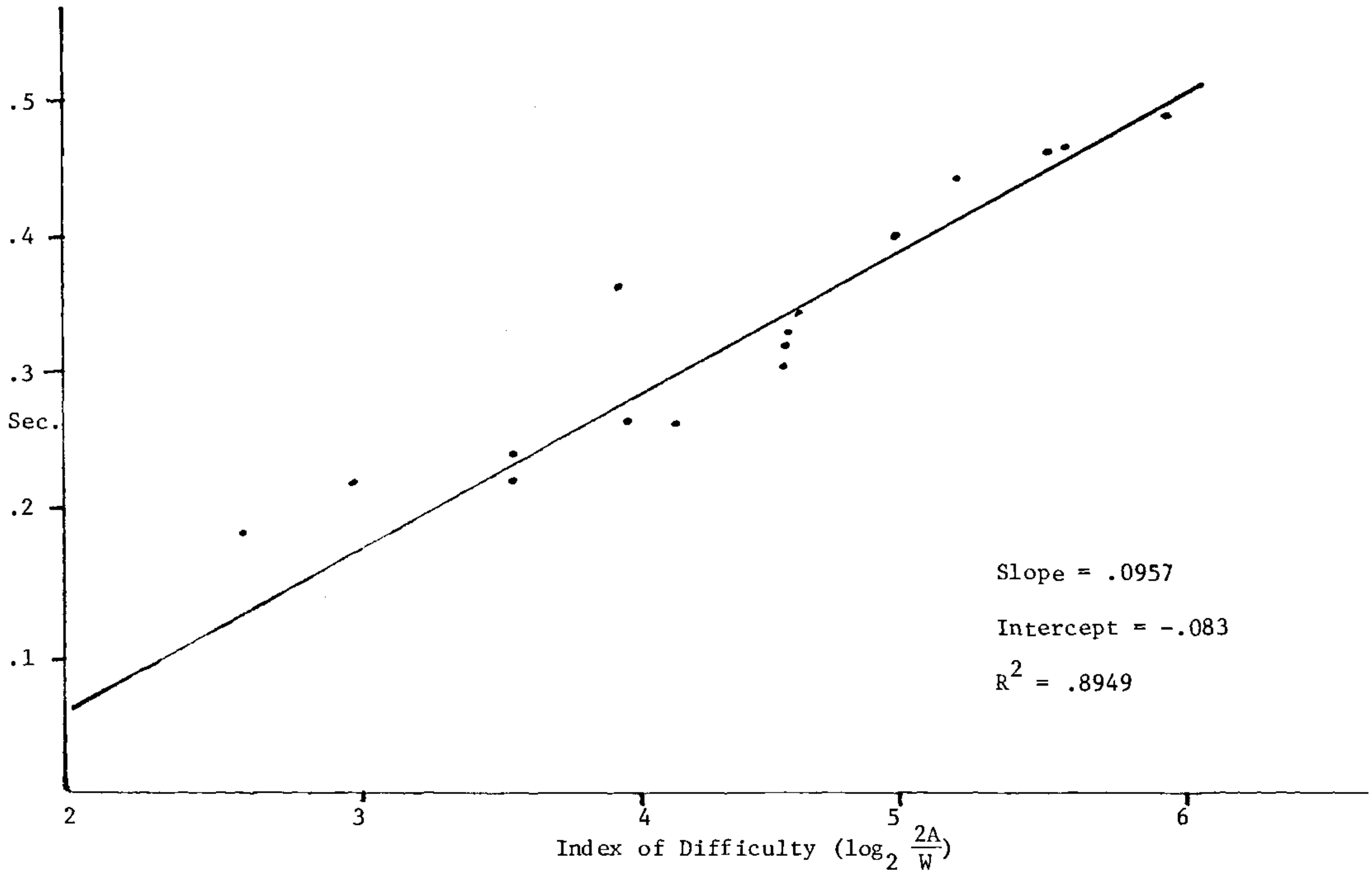


Figure 4-3. Mean Movement Time Averaged Across Subjects vs. Index of Difficulty for Mental Condition.

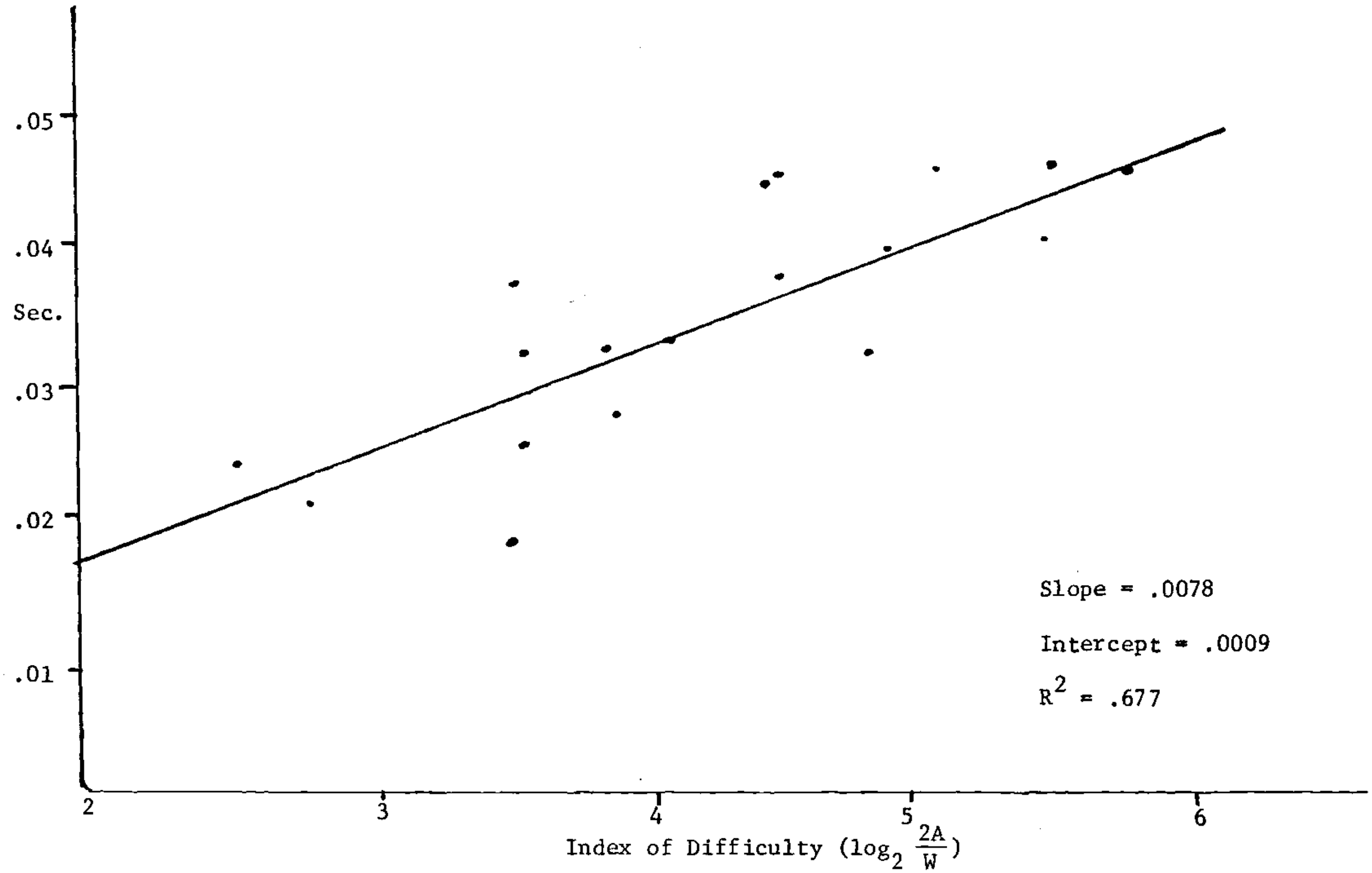


Figure 4-4. Standard Deviation of Movement Time Averaged Across Subjects vs. Index of Difficulty for Pause Condition.

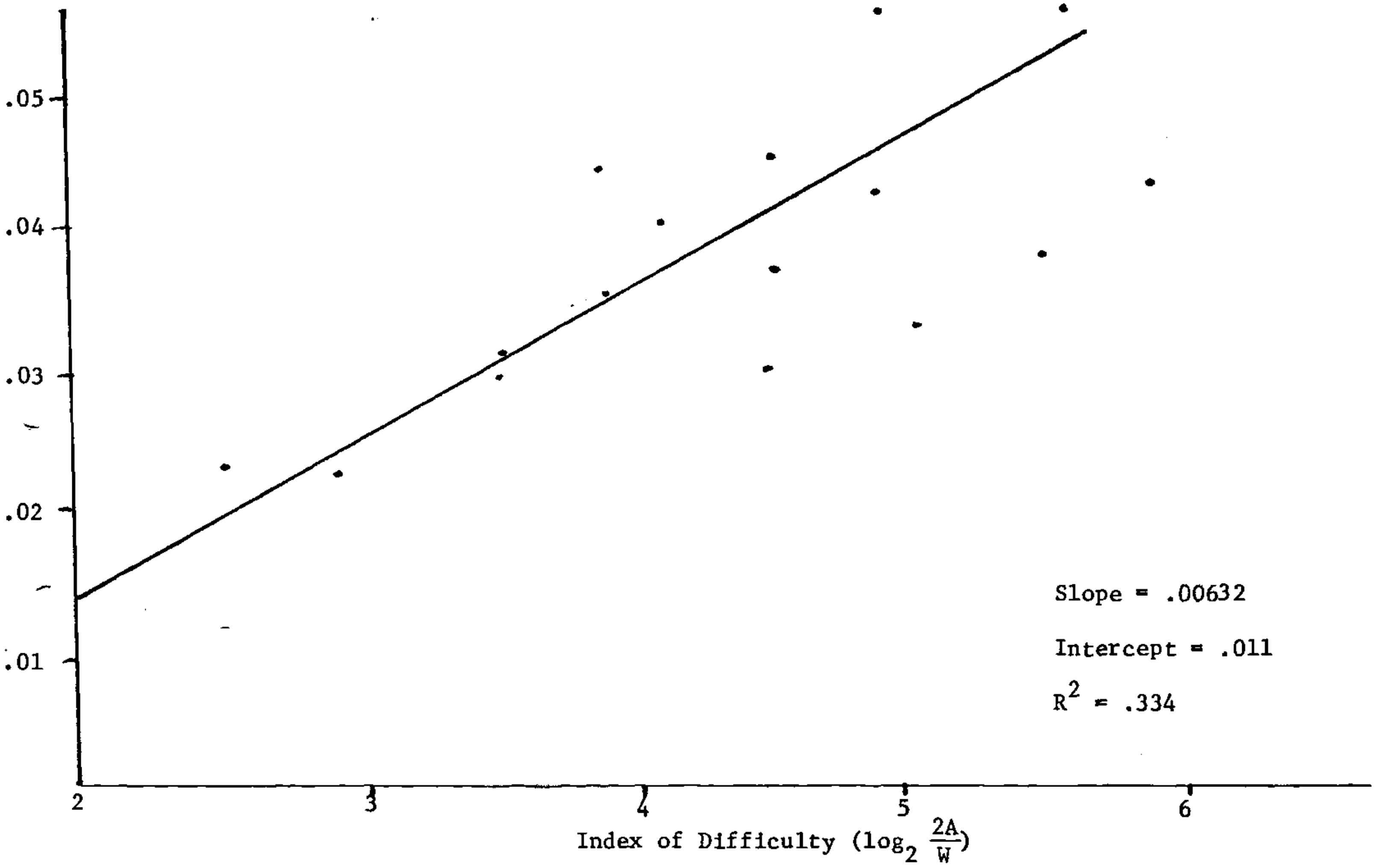


Figure 4-5. Standard Deviation of Movement Averaged Across Subjects vs. Index of Difficulty for Motor Condition.

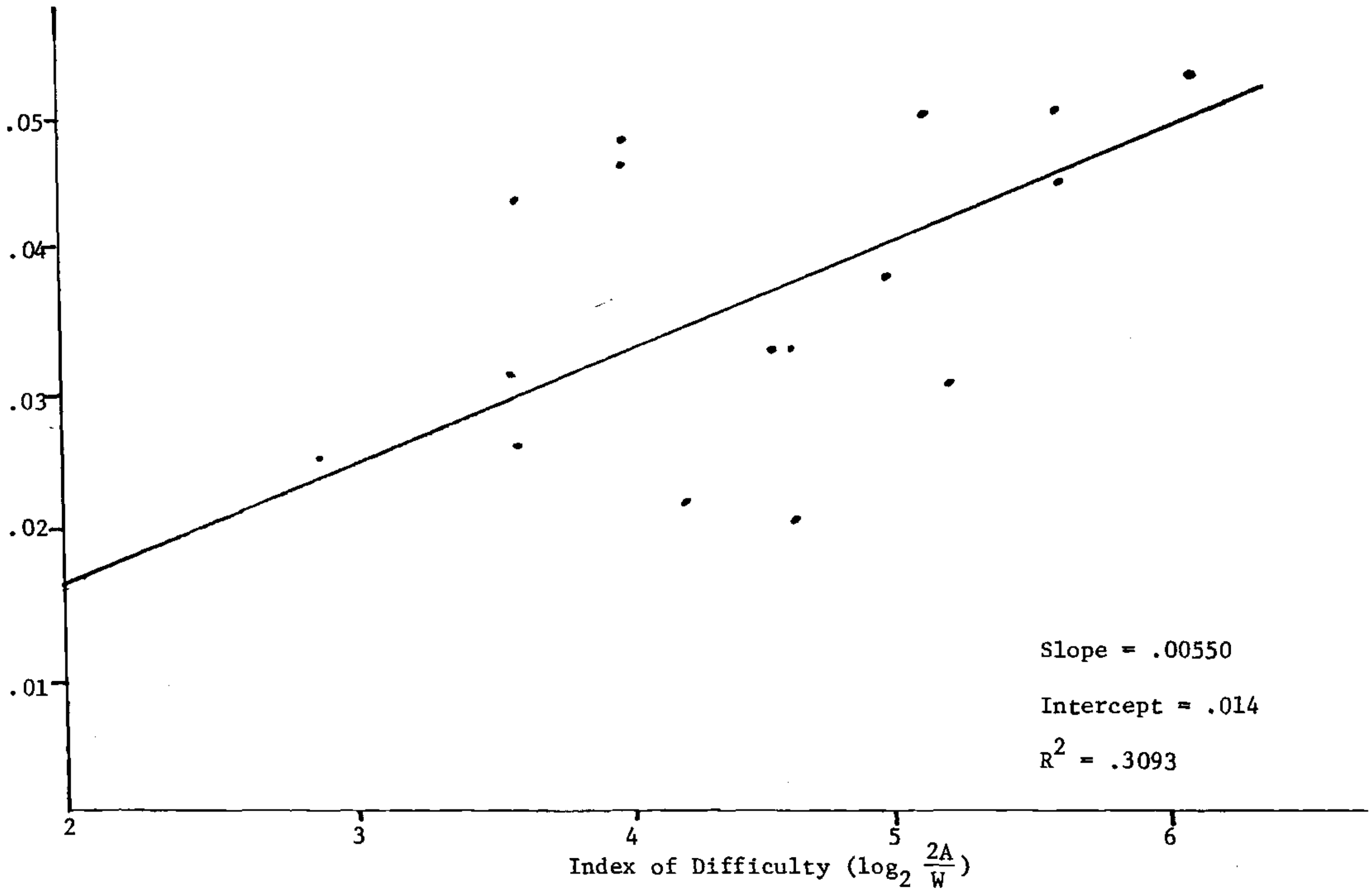


Figure 4-6. Standard Deviation of Movement Times Averaged Across Subjects vs. Index of Difficulty for Mental Condition.

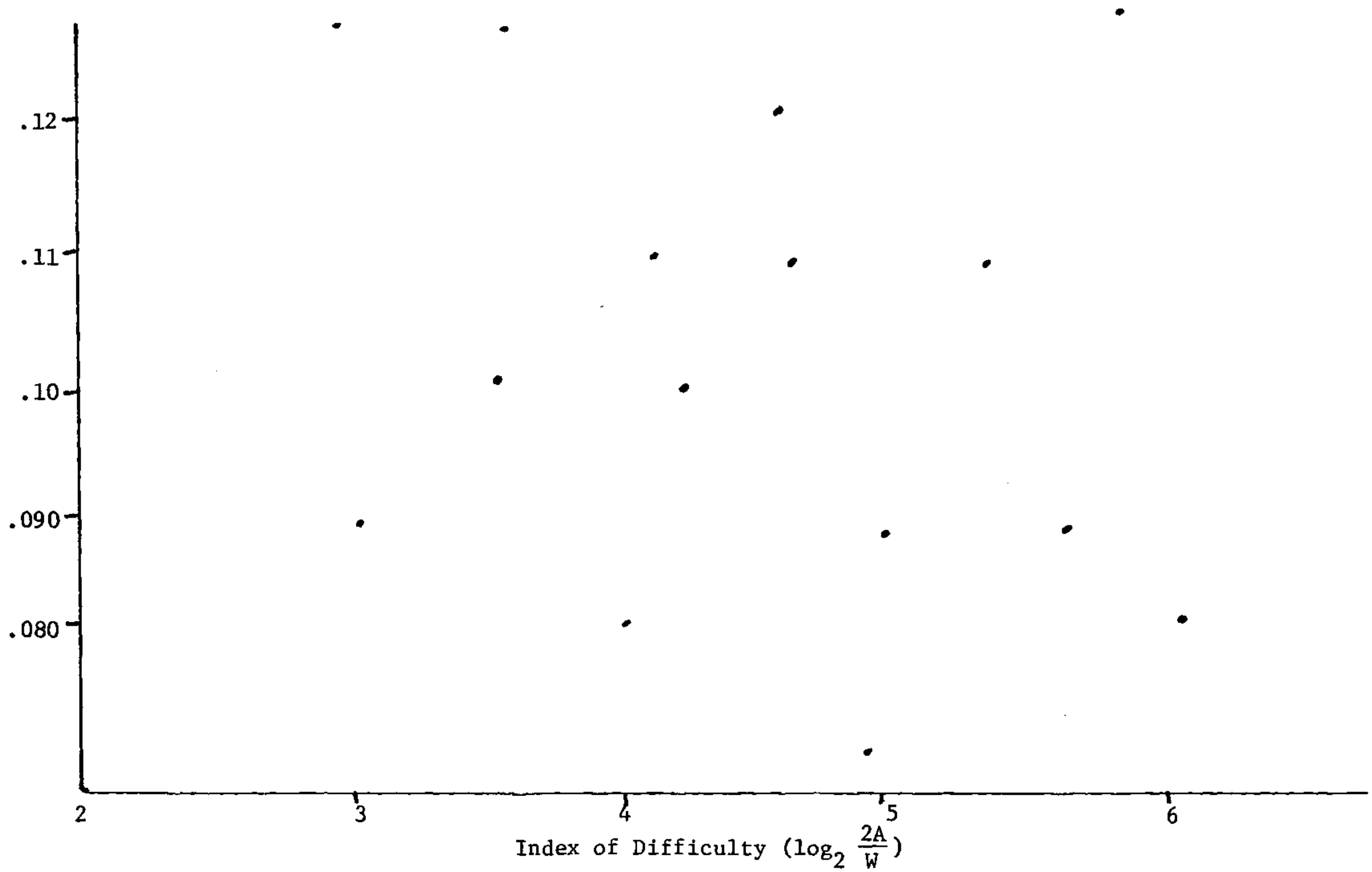


Figure 4-7. Coefficient of Variation Averaged Across Subjects vs. Index of Difficulty Pause Condition.

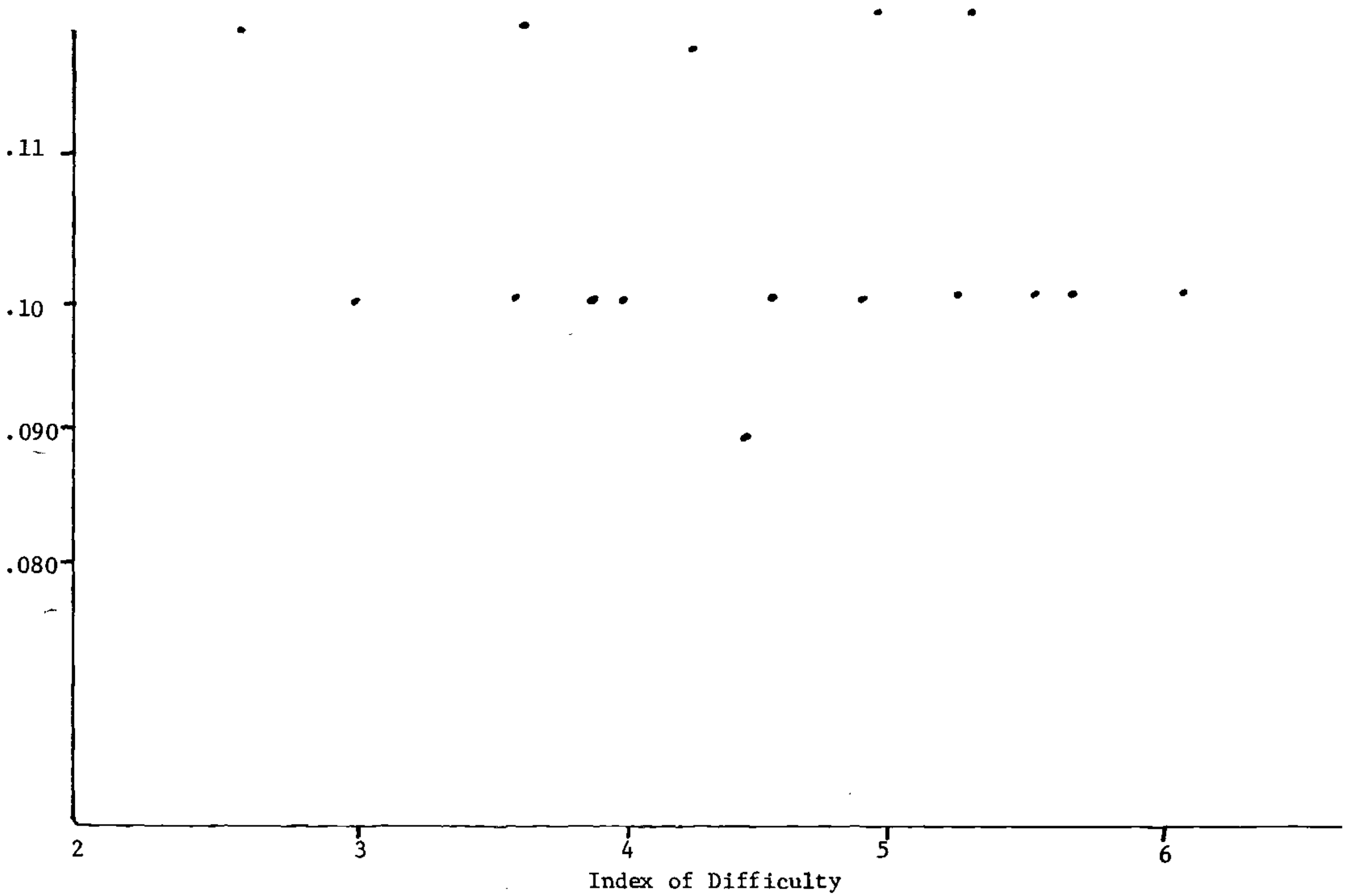


Figure 4-8. Coefficient of Variation Averaged Across Subjects vs. Index of Difficulty for Motor Condition.

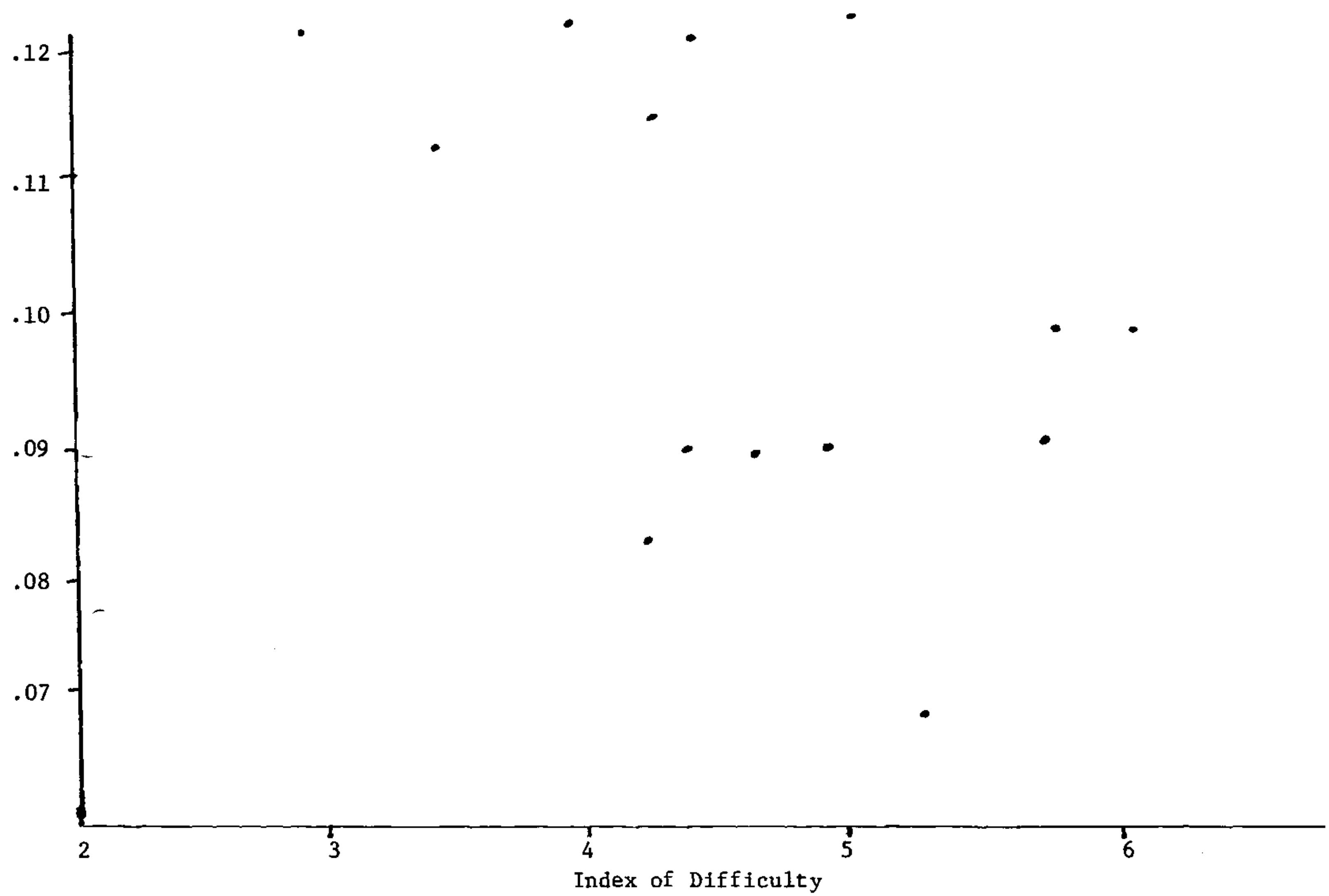


Figure 4-9. Coefficient of Variation Across Subjects vs. Index of Difficulty for Mental Condition.

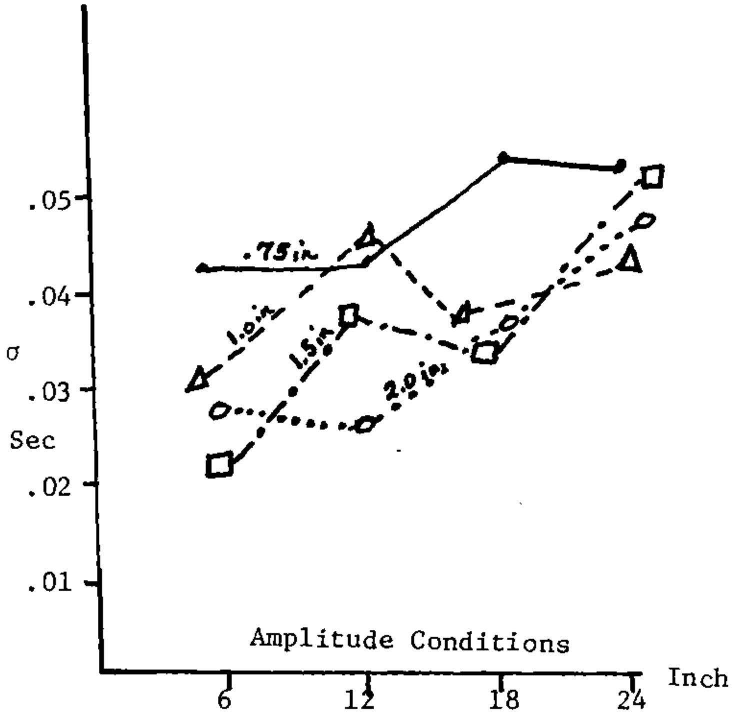


Figure 4-10. Changes in Standard Deviation with Increasing Amplitude.

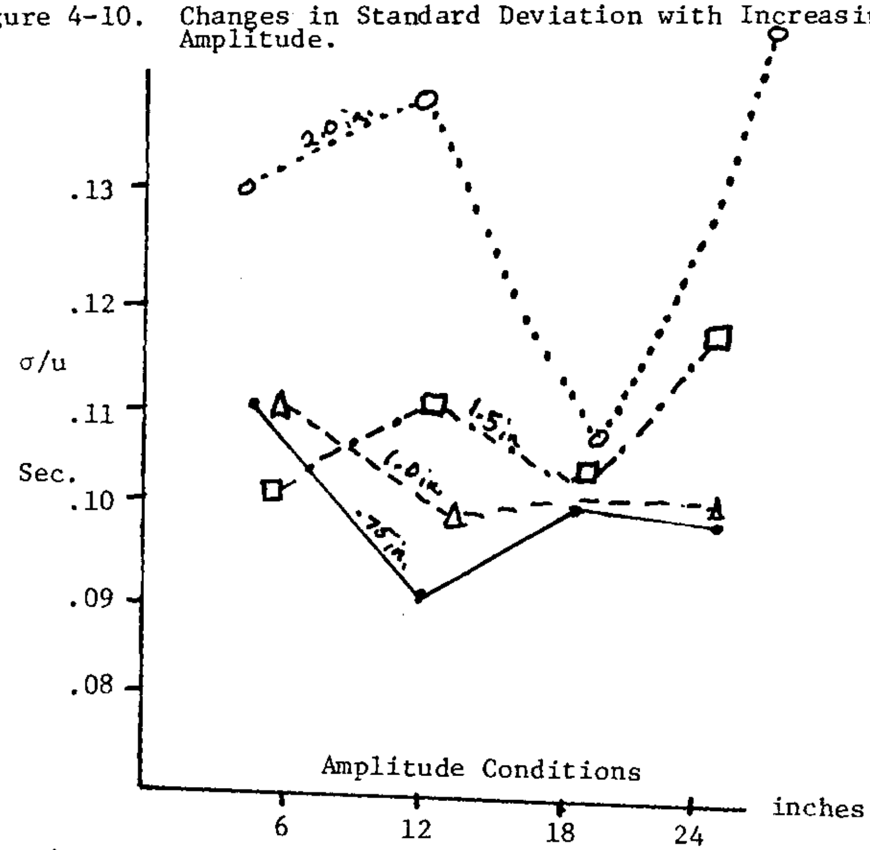


Figure 4-11. Changes in Coefficient of Variation with Increasing Amplitude.

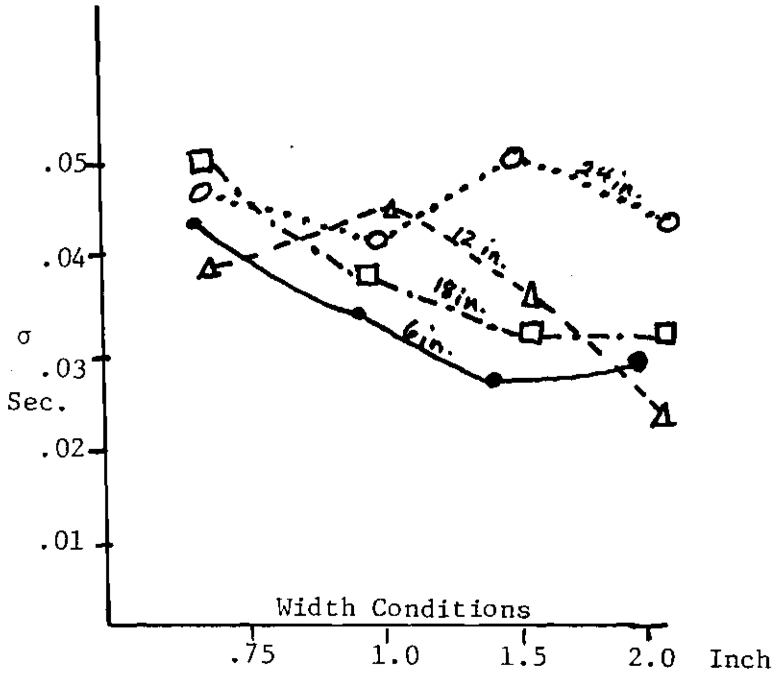


Figure 4-12. Changes in Standard Deviation with Increasing Width.

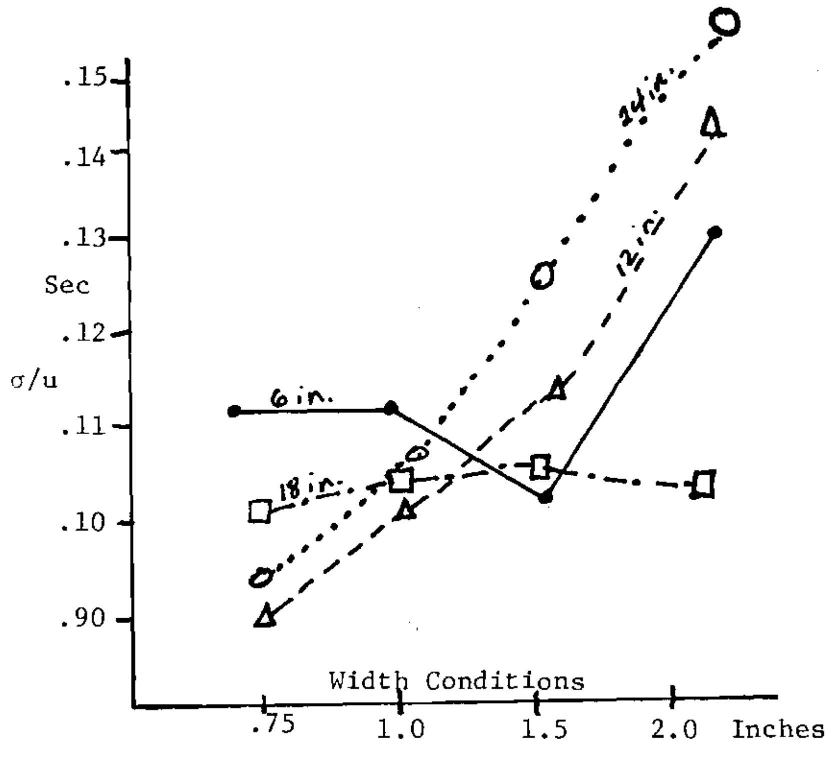


Figure 4-13. Changes in Coefficient of Variation with Increasing Width.

Table 4-5. Coefficients of Variation for Each Cell in the Design

Factor*	σ/u	Factor	σ/u	Factor	σ/u
111	.11	211	.10	311	.13
112	.07	212	.10	312	.09
113	.09	213	.10	313	.10
114	.08	214	.10	314	.10
121	.13	221	.10	321	.11
122	.11	222	.10	322	.09
123	.11	223	.10	323	.07
124	.13	224	.10	324	.09
131	.09	231	.10	331	.12
132	.08	232	.10	332	.17
133	.12	233	.09	333	.09
134	.09	234	.15	334	.12
141	.15	241	.12	341	.14
142	.10	242	.12	342	.20
143	.10	243	.14	343	.08
144	.20	244	.14	344	.13

*Variable levels indicated: First factor, Secondary task condition 1 = pause, 2 = motor, 3 = mental; Second factor - Target Width = .75 in., 2 = 1.0 in. 3 = 1.5 in., 4 = 2.0 in; Third factor - Movement Amplitude 1 = 6 in., 2 = 12 in, 3 = 18 in., 4 = 24 in.

Table 4-6. Analysis of Variance of Slopes and Intercepts for Within Subject's Regression Lines

Mean Times

Intercepts

	SS	d.f.	MS	F
Sec. Task	7.8×10^{-4}	3	2.6×10^{-4}	.09
Error	2.4×10^{-2}	9	2.66×10^{-3}	
Total	2.48×10^{-2}	12		

Slopes

	SS	d.f.	MS	F
Sec. Task	7.5×10^{-4}	3	2.5×10^{-4}	5.49
Error	4.1×10^{-4}	9	4.55×10^{-5}	
Total	1.16×10^{-3}	12		

Standard Deviations

Intercepts

	SS	d.f.	MS	F
Sec. Task	8.92×10^{-4}	3	2.97×10^{-4}	.61
Error	4.38×10^{-3}	9	4.86×10^{-4}	
Total	5.28×10^{-3}	12		

Slopes

	SS	d.f.	MS	F
Sec. Task	6×10^{-6}	3	2×10^{-6}	3.91×10^{-2}
Error	4.6×10^{-4}	9	5.11×10^{-5}	
Total	4.66×10^{-4}	12		

CHAPTER V

CONCLUSIONS

The analysis of results give rise to the following conclusions:

The first ANOVA model (Table 4-1) analyzed for each subject showed all factors were significant. All factors studied seemed to have an impact on mean performance time. This conclusion was not an unexpected result; because of the large number of degrees of freedom involved, this was an extremely sensitive test. One point to note however, is the relatively lower F values for the effects of secondary task condition on each subject.

The ANOVA models for the mean and standard deviations resulted in significant effects for width and amplitude measures but not for the secondary task condition. The ANOVA model for the coefficients of variation showed the amplitude as well as secondary task condition were not significant but width had a significant effect. This analysis on the coefficients of variation suggests that the precision of a movement may be an important variable in determining variability. The graphs in Figures 4-10 through 4-13 result in some interesting conclusions:

1. Increasing amplitude of movement results in an increase in the standard deviation of movement time (Figure 4-10).

2. Increasing target width results in a decreased standard deviation (Figure 4-12).

3. Increasing amplitude has little effect on the coefficients of variation (Figure 4-11). In order for this to happen we conclude that amplitude has a proportionate effect on both mean movement time and on the standard deviation of movement time.

4. Increased target width results in an increase in coefficient of variation (Figure 4-13). In order for this to happen we conclude that target width has a disproportionate effect on mean time and standard deviation. That is, reducing target widths will increase standard deviation to a larger degree than it will increase the mean time.

The above results are important in application areas where controlling task variability is an important factor. The impact these parameters have on mean performance time is obvious and well supported by research. It is not so obvious what controls task variability. The above conclusion adds a step in this direction.

The analysis using Fitts' model of performance indicated that Fitts' law does a good job in predicting mean performance. This conclusion supports the literature on this aspect of performance. This study has shown that Fitts' law does less adequate job in predicting the standard deviation of performance. The coefficients of determination were .80 or above for the means and .3 to .6 for the standard deviations. However, the F values showed significant regression for all regression lines for means and standard deviations at the .05 level. The larger variability in the standard deviation data was expected because the analysis was based on 50 data points. This estimation is not nearly as precise as that for the mean. Estimates for the standard deviation using 50 data points can be expected to vary as much as ±14% (Crow, 1960, p. 277).

The analysis of the slopes and intercepts (Table 4-6) for subjexts gives the overall conclusion that secondary task had little effect on the Fitts' model. This conclusion is consistent with the conclusions of the second ANOVA models (Tables 4-2 through 4-4).

The analysis of using the Fitts' model with the coefficient of variation showed no significant regression with index of difficulty.

Comparing the different analyses used in this study points to the fact that averaging data across subjects gives relatively clean predictors of performance, when predicting individual performance the models investigated are relatively imprecise. Using average data with Fitts' law is a good model for mean performance time as shown in the literature. This study indicates it to be an acceptable but less precise model for standard deviation. Secondary task conditions showed lower significance than other factors.

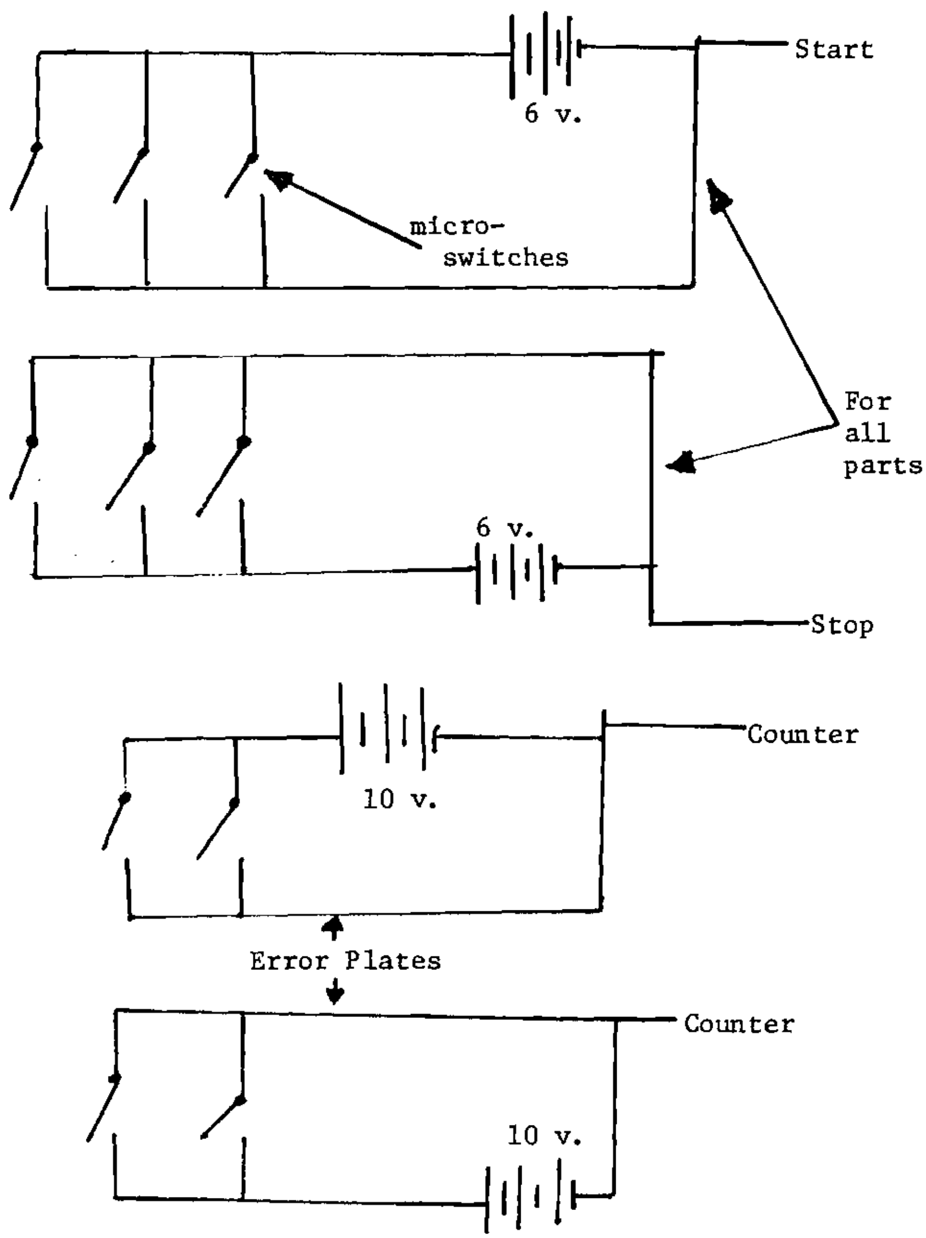
Suggestions for Further Study

There are several logical extensions that can be performed. One such extension is using unequal target widths for the Fitts' task. In most of the literature on the Fitts' task, both targets are the same width for each experimental condition. There may be possible differences in performance when the targets are unequal. Another extension would be to examine different time intervals and complexities of the secondary task. This study points out the need for examining critically the statistical measures used in performing an analysis of psychomotor performance.

A suggestion for further would be to examine in detail the different statistical parameters, such as slowness might be used.

APPENDIX A

CIRCUIT DIAGRAM



APPENDIX B

A TYPICAL WORD LIST FOR MENTAL TASK

1.	left	ride	think
2.	top	won	try
3.	page	rose	west
4.	heat	tend	last
5.	hope	walk	took
6.	mine	hard	wear
7.	about	good	stuck
8.	play	year	feel
9.	head	know	cause
10.	form	sure	small
11.	make	have	type
12.	write	live	lead
13.	fine	round	fail
14.	new	trade	gate
15.	pop	peace	black
16.	all	quite	world
17.	give	serve	main
18.	inch	role	any
19.	are	fall	go
20.	want	line	not
21.	much	peak	rate
22.	grasp	hand	high
23.	end	place	say
24.	twelve	it	top
25.	clear	under	at
26.	meet	check	were
27.	in	form	at
28.	eight	some	sound
29.	can	sit	easy
30.	did	long	need
31.	let	speed	fan
32.	be	man	great
33.	norm	pay	real
34.	shape	part	first
35.	one	job	path
36.	look	move	three
37.	not	right	what
38.	ought	find	have
39.	go	vary	two
40.	break	five	each
41.	aid	order	teeth
42.	with	could	stand
43.	this	most	lab
44.	fact	use	train
45.	skill	that	sound
46.	been	how	well
47.	these	time	task
48.	work	been	rate
49.	put	home	take
50.	pack	add	known

APPENDIX C

Table C-1. Mean Reaction Times

	Subject				
Factor*	1	2	3	4	MT=5**
111	.1786	.3709	.3483	.2905	.2971
112	.3870	.3505	.4631	.6274	.4570
113	.3860	.4006	.5669	.4228	.4441
114	.5284	.4653	.6094	.4278	.5077
121	.1791	.2448	.3227	.2800	.2566
123	.3026	.3609	.4946	.4047	.3907
124	.5201	.4397	.3666	.4299	.3401
131	.1442	.1929	.2512	.2252	.2034
132	.3070	.2508	.3907	.2631	.3029
133	.1975	.2838	.4743	.2903	.3115
134	.4983	.3624	.5015	.3929	.4388
141	.1293	.1416	.1982	.1586	.1569
142	.1492	.1907	.3153	.2204	.2189
143	.1842	.2026	.3639	.2351	.2464
144	.1923	.2113	.3795	.3239	.2767
211	.2692	.3539	.3170	.2668	.3017
212	.4422	.4289	.5862	.3691	.3251
213	.3728	.4613	.5027	.4069	.4359
214	.3485	.3767	.5729	.4029	.4253
221	.2087	.2682	.3315	.2539	.2656
222	.4751	.3900	.5094	.2992	.4184
223	.3442	.4025	.5145	.3868	.4145
224	.4795	.4192	.4931	.5140	.4764
231	.1536	.1881	.2726	.2259	.1860
232	.2171	.2128	.4469	.3078	.2961
233	.2558	.3696	.3749	.3207	.3302
234	.2131	.4277	.4997	.4222	.3894
241	.1002	.1451	.3438	.1792	.1921
242	.1745	.2324	.3758	.3-00	.2707
243	.3006	.2060	.4054	.2719	.2960
244	.2010	.2384	.3826	.2709	.2732

Table C-1. (Continued)

Factor*	1	2	3	4	MT=5**
311	.2335	.3732	.3751	.4347	.3543
312	.4167	.4727	.3725	.3523	.4036
313	.4477	.4665	.4888	.4540	.4643
314	.4606	.4416	.5834	.4615	.4868
321	.2109	.2194	.3696	.2741	.2685
322	.2824	.3559	.3940	.3175	.3375
323	.4152	.4202	.5193	.4124	.4417
324	.4097	.4191	.5993	.4670	.4738
331	.1740	.2296	.2673	.2294	.2251
332	.2342	.2522	.3307	.2701	.2718
333	.3955	.3061	.3972	.3353	.3588
334	.3134	.3775	.4894	.4228	.4008
341	.1288	.1408	.3032	.1874	.1901
342	.1856	.1950	.2828	.2302	.2234
343	.2122	.2451	.3335	.2741	.2662
344	.2306	.2248	.4198	.3266	.3005

*Variable levels indicated: Sec. Task - 1 - Pause, 2 = motor, 3 - mental; 1 = .75 in., 2 - 1.0 in., 3 - 1.5 in. 4 = 2.0 in widths; Amplitudes 1 = 6 in., 2 = 12 in., 3 = 18 in., 4 - 24 in.

**MT - movement times averaged across subjects

Table C-2. Standard Deviations

	Subject				
Factor*	1	2	3	4	MT
111	.0212	.0257	.0433	.0431	.0333
112	.1185	.0307	.0435	.0395	.0331
113	.0628	.0238	.0445	.0918	.0402
114	.0767	.0213	.0554	.0282	.0454
121	.0465	.0219	.0301	.0350	.0447
122	.0698	.0339	.0318	.0450	.0447
123	.0652	.0243	.0415	.0440	.0438
124	.0649	.0491	.0384	.0324	.0462
131	.0162	.0230	.0229	.0180	.0200
132	.0363	.0202	.0318	.0199	.0270
133	.0549	.0280	.0296	.0402	.0382
134	.0519	.0256	.0428	.0424	.0407
141	.0547	.0132	.0197	.0117	.0248
142	.0223	.0175	.0197	.0182	.0194
143	.0879	.0136	.0219	.0162	.0349
144	.1120	.0227	.0203	.0276	.0457
211	.0862	.0261	.0404	.0245	.0443
212	.0488	.0241	.0583	.0465	.0444
213	.0807	.0333	.0796	.0340	.0569
214	.0665	.0236	.0365	.0442	.0427
221	.0231	.0314	.0322	.0280	.0287
222	.0850	.0185	.0453	.0307	.0449
223	.0325	.0317	.0424	.0274	[illegible]
224	.0443	.0174	.0366	.0536	[illegible]
231	.0276	.0204	.0207	.0203	[illegible]
232	.0450	.0405	.0311	.0246	.0353
233	.0581	.0179	.0610	.0303	.0293
234	.1073	.0279	.0536	.0377	[illegible]
241	.0236	.0122	.0283	.0271	[illegible]
242	.0195	.0402	.0289	.0491	.0319
243	.0706	.0215	.0308	.0391	.0405
244	.0855	.0174	.0207	.0256	.0373

Table C-2. (Continued)

	Subject				
Factor*	1	2	3	4	MT
311	.0474	.0252	.0381	.0702	.0452
312	.0619	.0277	.0303	.0322	.0280
313	.0685	.0272	.0417	.0604	.0494
314	.0620	.0221	.0712	.0554	.0526
321	.0269	.0386	.0388	.0227	.0318
322	.0562	.0224	.0258	.0301	.0366
323	.0270	.0232	.0468	.0318	.0322
324	.0557	.0227	.0638	.0366	.0447
331	.0499	.0264	.0175	.0169	.0277
332	.1126	.0319	.0259	.0225	.0482
333	.0380	.0449	.0234	.0279	.0335
334	.1033	.0259	.0364	.0322	.0495
341	.0196	.0176	.0537	.0155	.0266
342	.1116	.0210	.0324	.0137	.0447
343	.0378	.0187	.0280	.0159	.0226
344	.0847	.0250	.0298	.0207	.0400

*Variable levels indicated: Sec. Task - 1 = Pause, 2 = motor, 3 = mental; widths 1 = .75 in., 2 = 1.0 in., 3 = 1.5 in., 4 = 2.0 in.; Amplitudes 1 = 6 in., 2 = 12 in., 3 = 18 in., 4 = 24 in.

**MT - Movement times averaged across subjects

Table C-3. Coefficients of Variation

Factor*	1	2	3	4
111	.118	.069	.124	.148
112	.306	.087	.093	.062
113	.162	.059	.078	.217
114	.1451	.045	.090	.060
121	.259	.089	.093	.125
122	.170	.090	.079	.109
123	.215	.067	.083	.108
124	.124	.111	.104	.075
131	.-12	.119	.091	.079
132	.118	.080	.081	.079
133	.277	.098	.062	.075
134	.104	.070	.085	.138
141	.423	.093	.099	.073
142	.149	.091	.062	.082
143	.477	.067	.060	.068
144	.582	.107	.053	.085
211	.320	.073	.127	.091
212	.110	.056	.099	.125
213	.216	.077	.158	.083
214	.190	.062	.063	.109
221	.110	.117	.097	.110
222	.178	.047	.088	.102
223	.094	.078	.082	.070
224	.092	.041	.074	.104
231	.179	.108	.075	.089
232	.207	.190	.069	.080
233	.227	.048	.162	.094
234	.503	.065	.107	.089
241	.235	.084	.082	.151
242	.111	.172	.076	.163
243	.234	.104	.075	.143
244	.425	.072	.054	.094

Table C-3. (Continued)

Factor*	1	2	3	4
311	.202	.067	.101	.161
312	.148	.058	.081	.091
313	.153	.058	.083	.133
314	.134	.050	.122	.120
321	.127	.175	.104	.082
322	.199	.062	.065	.094
323	.065	.055	.090	.077
324	.135	.054	.238	.078
331	.286	.114	.052	.073
332	.480	.126	.065	.083
333	.095	.146	.058	.083
334	.329	.068	.074	.076
341	.152	.125	.177	.082
342	.601	.107	.114	.059
343	.131	.076	.083	.058
344	.367	.111	.070	.063

*Variable levels indicated: Sec. Task - 1 = Pause, 2 = motor, 3 = mental; widths 1 = .75 in., 2 = 1.0 in., 3 = 1.5 in., 4 = 2.0 in.;
Amplitudes 1 = 6 in., 2 - 12 in., 3 = 18 in., 4 = 24 in.

APPENDIX D

Table D-1. Linear Regression Coefficients: Slopes and Intercepts for Means

Slope Coefficients for Mean Times

(sec/ID)

Condition	Subjects 1	2	3	4	Across Subjects
Pause	.0827	.0904	.0898	.09568	.0951
Motor	.09149	.0907	.0825	.0796	.0836
Mental	.1060	.0970	.0948	.0850	.0957

Intercepts

(Sec)

Condition	Subjects 1	2	3	4	Across Subjects
Pause	-.0584	-.0987	-.0095	-.0868	-.0943
Motor	-.1211	-.0828	.0665	-.0283	-.0401
Mental	-.1740	-.1096	-.0129	-.0366	-.0834

Table D-2. Linear Regression Coefficients: Slopes and Intercepts of Standard Deviation

	Slope Coefficients for Standard Deviations (Sec/ID)				
	Subjects				
Condition	1	2	3	4	Across Subjects
Pause	.0155	.0046	.0087	.0113	.00782
Motor	.0143	.0022	.0052	.0053	.00632
Mental	.0054	.00002	.0068	.0100	.00550

	Intercepts (Sec)				
	Subjects				
Condition	1	2	3	4	Across Subjects
Pause	-.0090	.0039	-.0054	-.0157	.00096
Motor	-.0070	.0149	.01717	.0104	.0110
Mental	.0354	.0262	.0070	-.0131	.0144

Table D-3. Significance of Regression for Subject Averages for Mean Times

Pause Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig.	R^2
Regression	1	.12317	.12317	51.34	.001	.7857
Residual	14	.03359	.0024			

Motor Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig.	R^2
Regression	1	.0950	.0959	69.4	.0001	.83227
Residual	14	.0191	.0013			

Mental Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig.	R^2
Regression	1	.1247	.1247	119.23	.001	.8949
Residual	14	.0146	.0010			

Table D-4. Significance of Regression for Subject Averages for Standard Deviations

Pause Condition

Analysis of Variance	D.F.	SS	MS	4	Sig	R^2
Regression	1	.00083	.00083	29.4	.001	.677
Residual	14	.00040	.00003			

Motor Condition

Analysis of Variance	D.F.	SS	MS	F	Sig	R^2
Regression	1	.00054	.00054	7.032	.01	.334
Residual	14	.0010	.00008			

Mental Condition

Analysis of Variance	D.F.	SS	MS	F	Sig	R^2
Regression	1	.00041	.00041	6.27	.02	.3093
Residual	14	.00092	.00007			

APPENDIX E

Table E-1. Significance of Regression for Coefficient of Variation and Index of Difficulty

Pause Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig	R^2
Regression	1	.00148	.00148	1.53	.23	.098
Residual	14	.01354	.00097			

Motor Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig	R^2
Regression	1	.00007	.00007	.191	.66	.013
Residual	14	.00493	.00035			

Mental Condition						
Analysis of Variance	D.F.	SS	MS	F	Sig	R^2
Regression	1	.00008	.00008	.067	.79	.0047
Residual	14	.01672	.00119			

APPENDIX F

SUBJECT'S GRAPHS

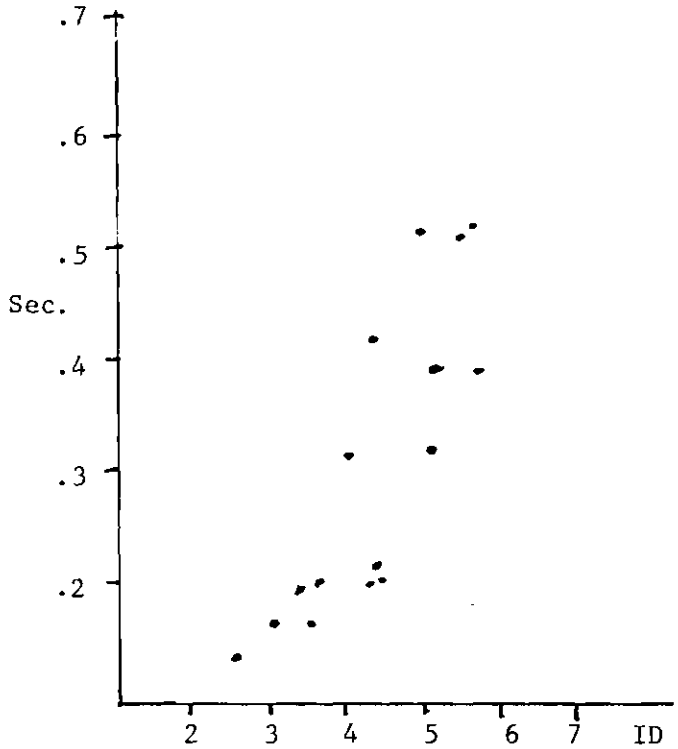


Figure F-1. Subject 1 Mean Pause Condition.

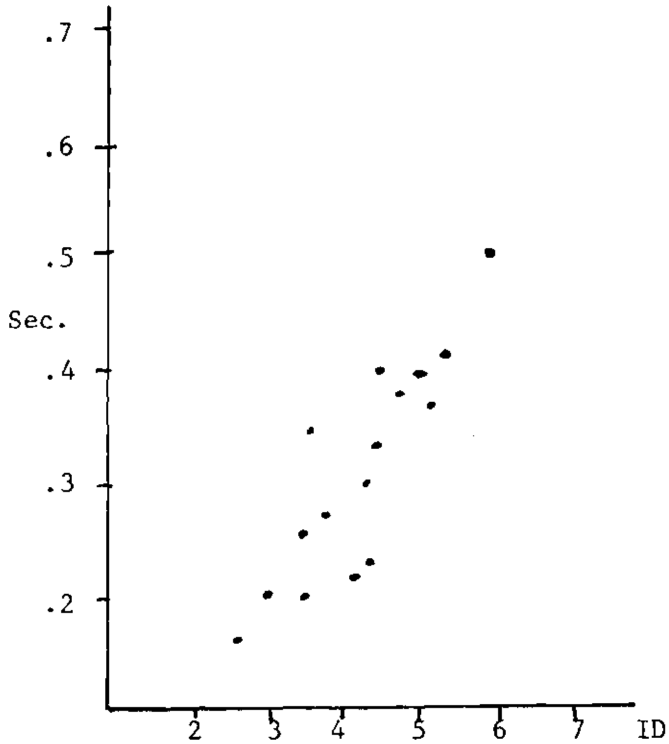


Figure F-2. Subject 2 Mean Pause Condition.

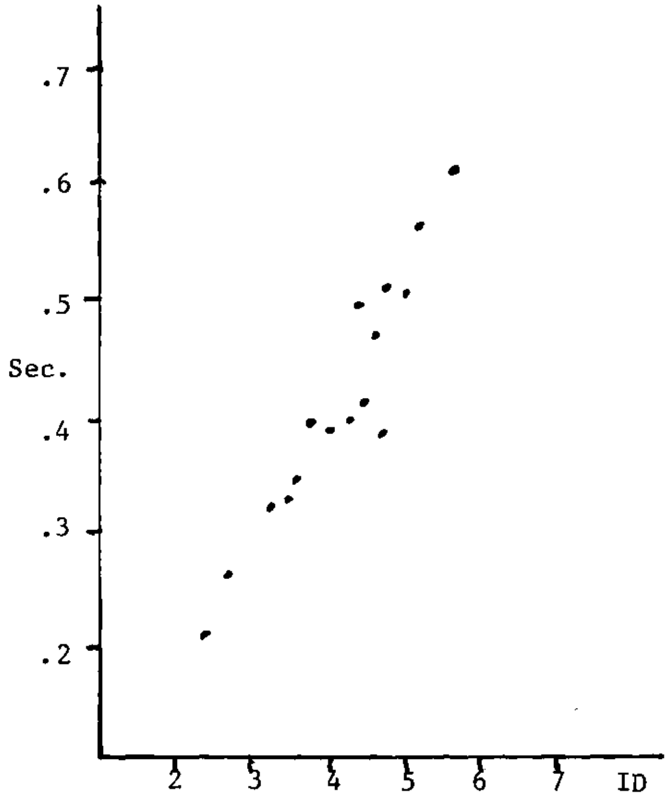


Figure F-3. Subject 3 Mean Pause Condition

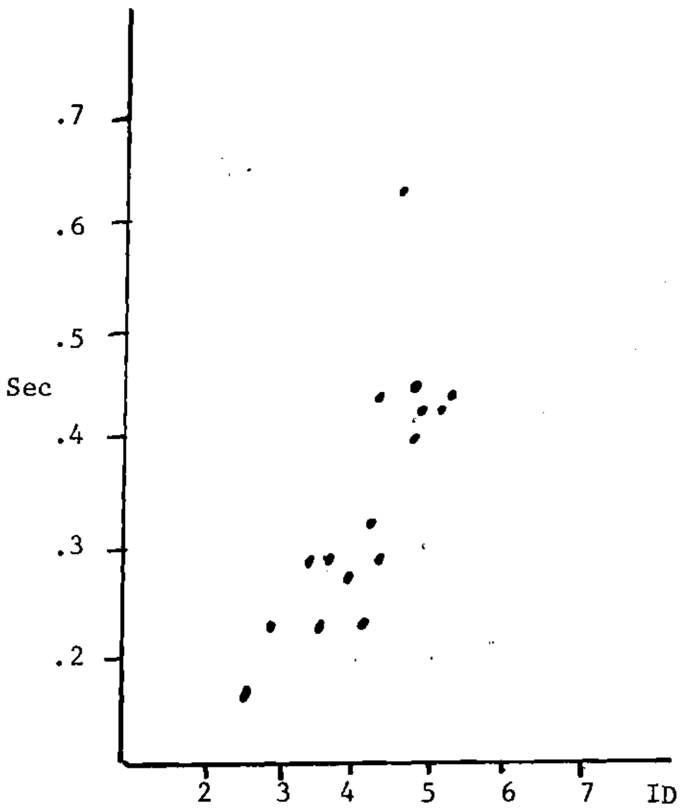


Figure F-4. Subject 4 Mean Pause Condition.

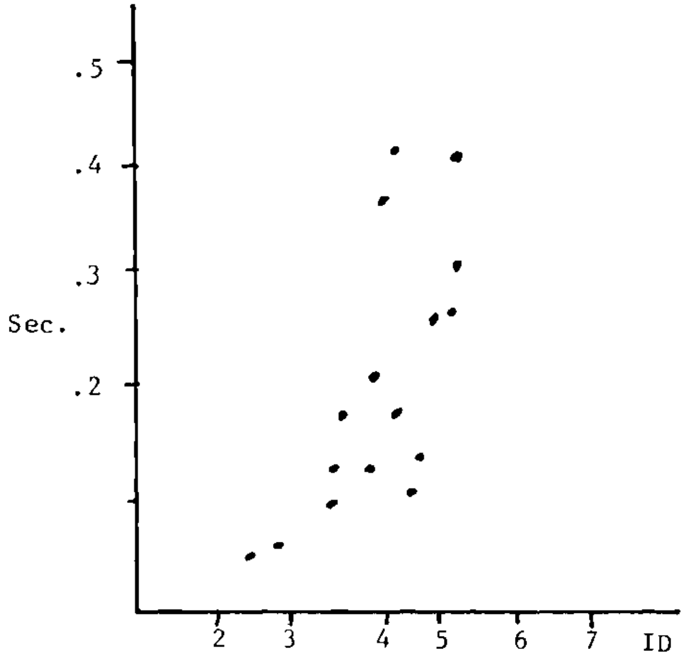


Figure F-5. Subject 1, Mean Motor Condition.

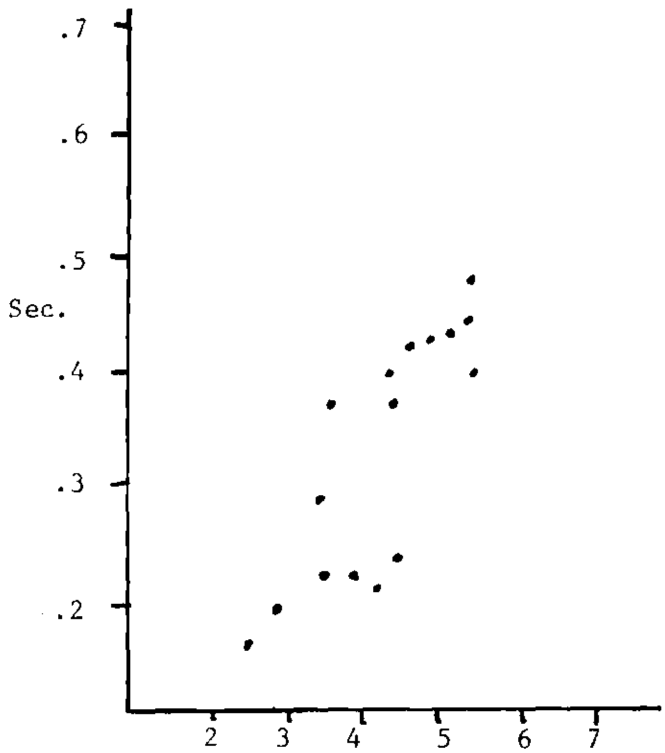


Figure F-6. Subject 2, Mean Motor Condition.

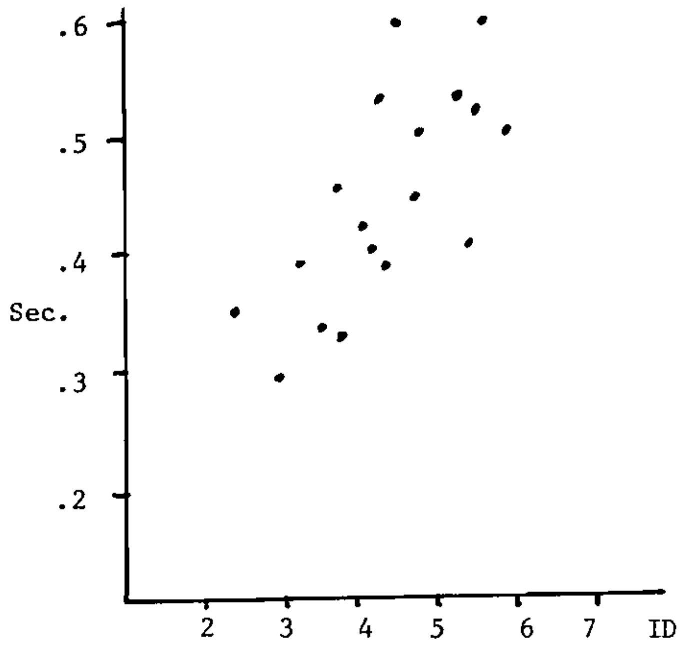


Figure F-7. Mean Motor Condition, Subject 3.

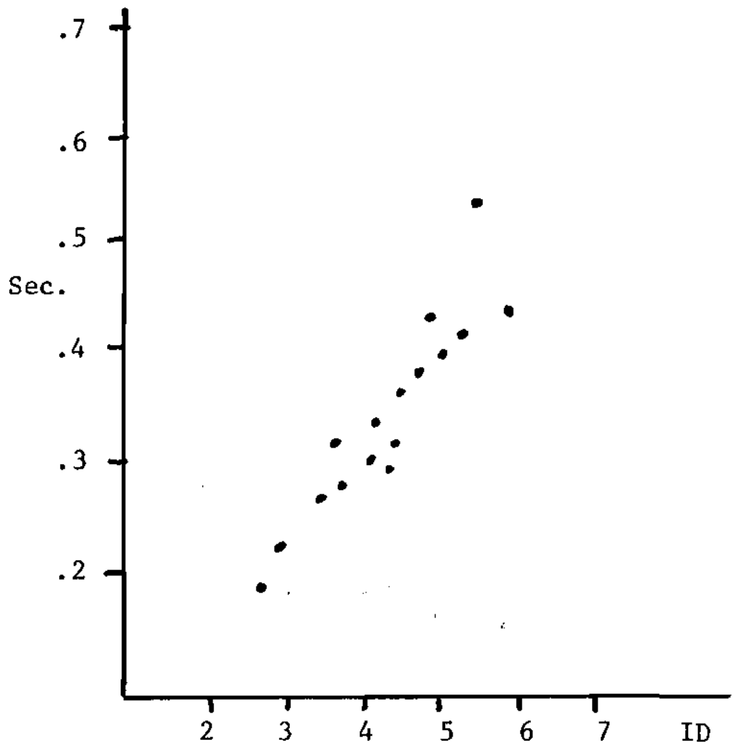


Figure F-8. Subject 4, Mean Motor Condition.

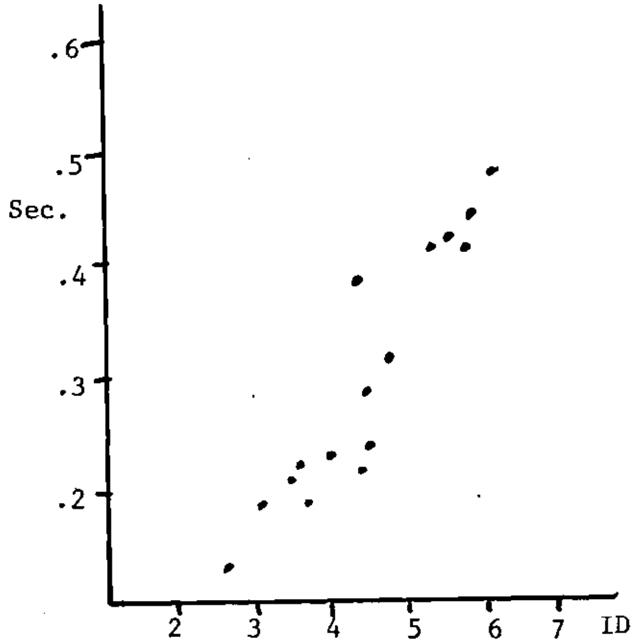


Figure F-9. Subject 1, Mean, Mental Condition.

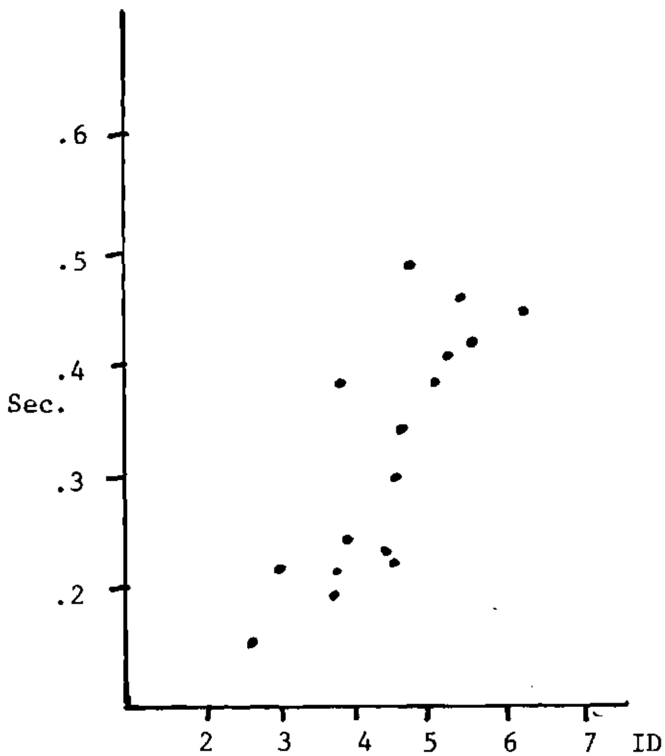


Figure F-10. Subject 2, Mean, Mental Condition.

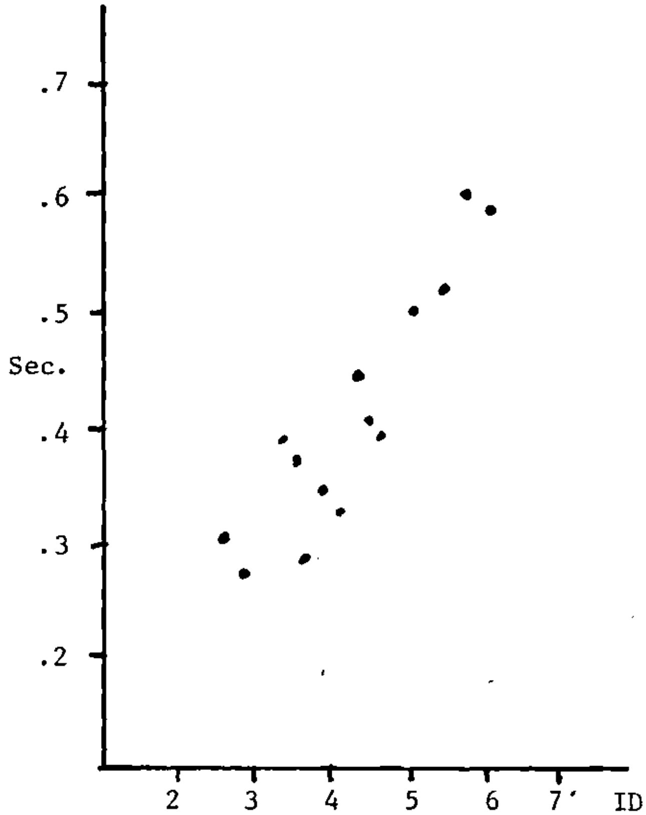


Figure F-11. Subject 3, Mean, Mental Condition.

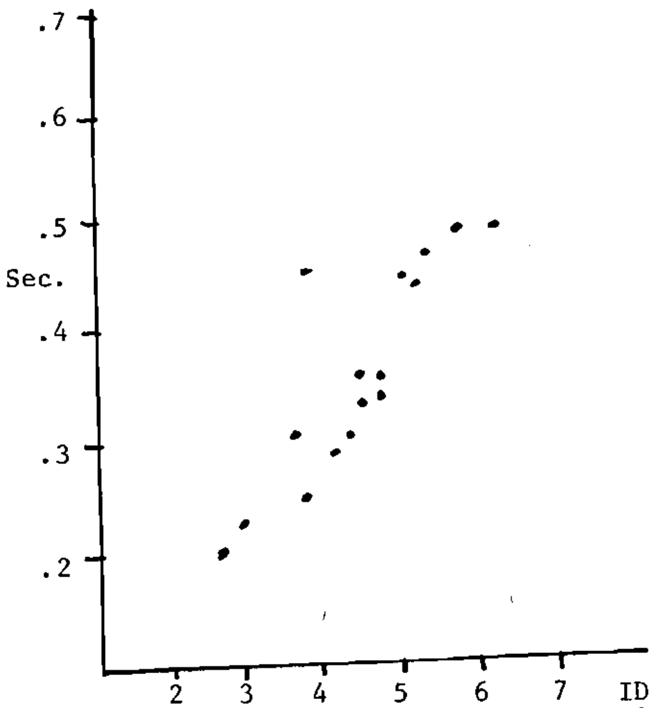


Figure F-12. Subject 4, Mean, Mental Condition.

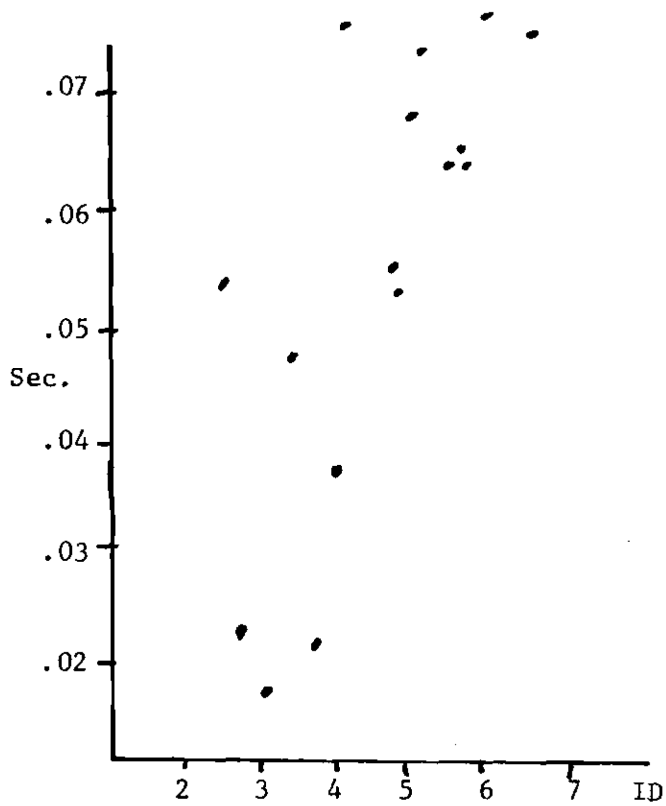


Figure F-13. Subject 1 Standard Deviation Pause Condition.

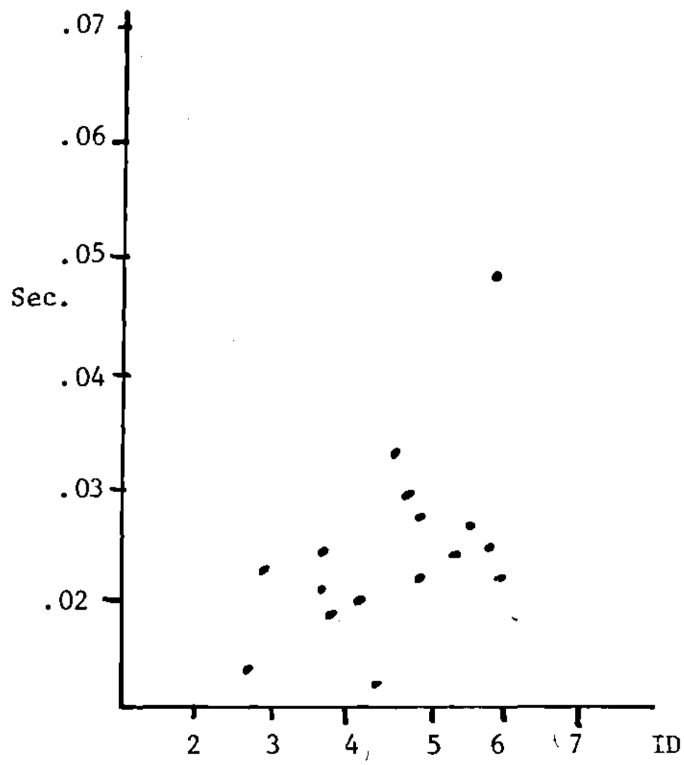


Figure F-14. Subject 2 Standard Deviation Pause Condition.

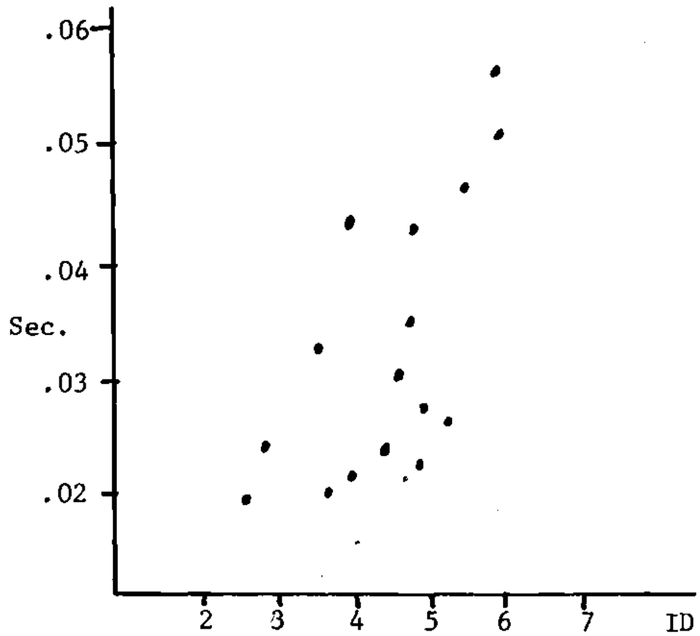


Figure F-15. Subject 3 Standard Deviation Pause Condition.

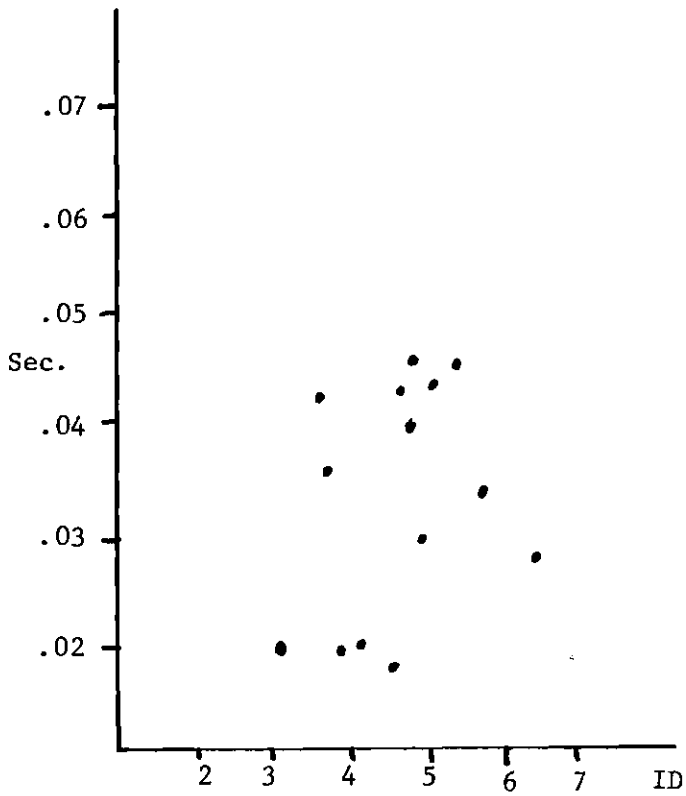


Figure F-16. Subject 4 Standard Deviation Pause Condition.

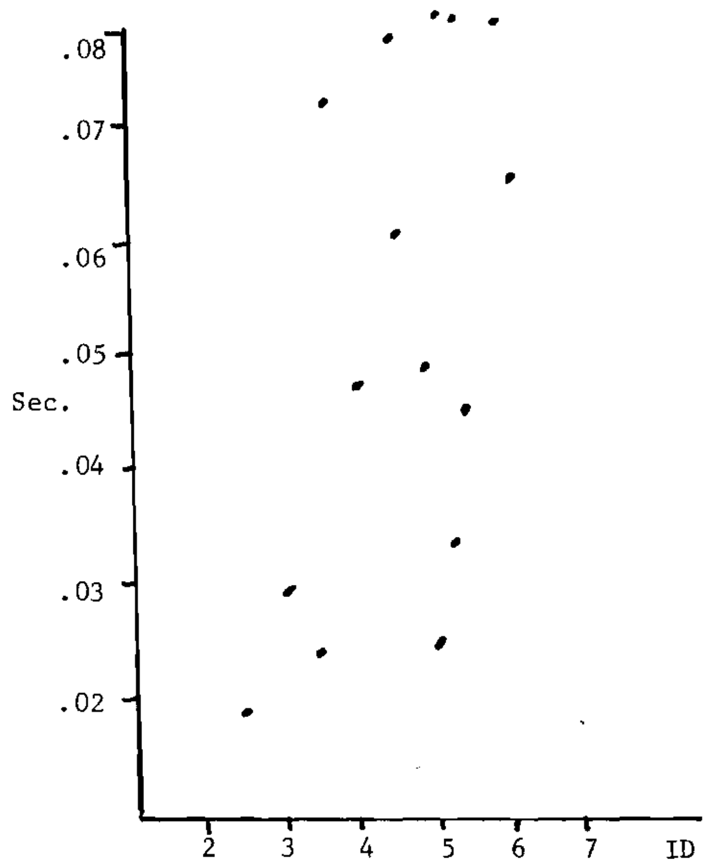


Figure F-17. Standard Deviation Subject 1, Motor Condition.

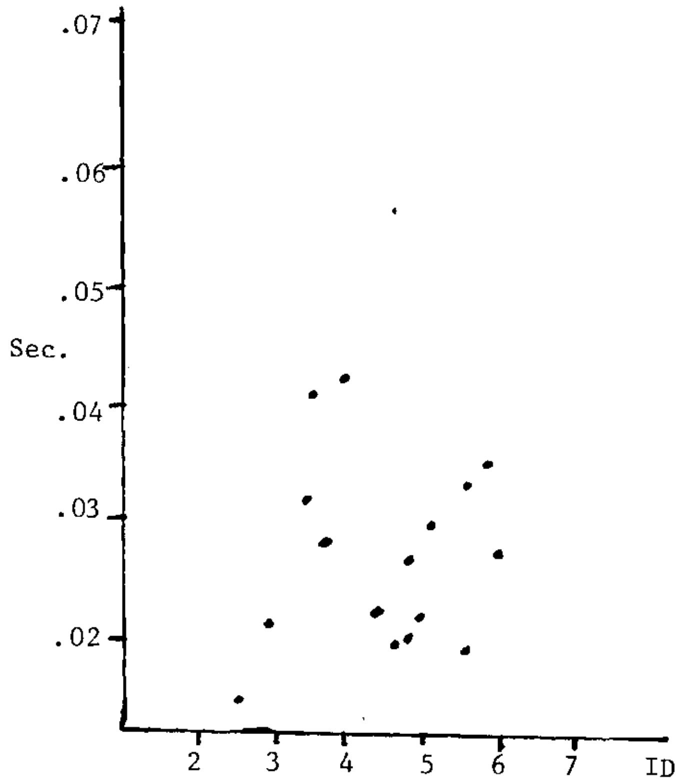


Figure F-18. Subject 2 Standard Deviation, Motor Condition.

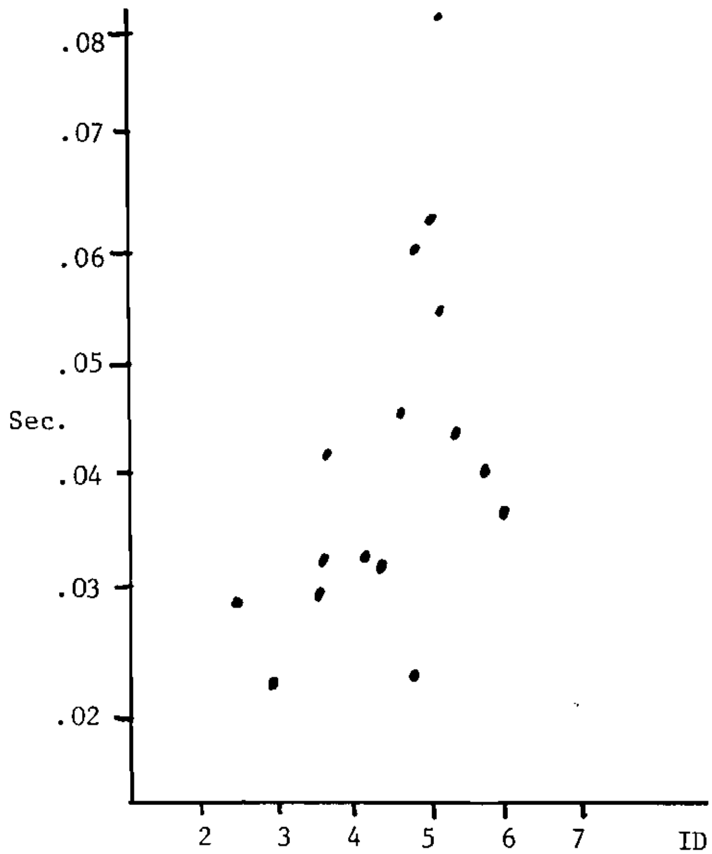


Figure F-19. Subject 3 Standard Deviation Motor Condition.

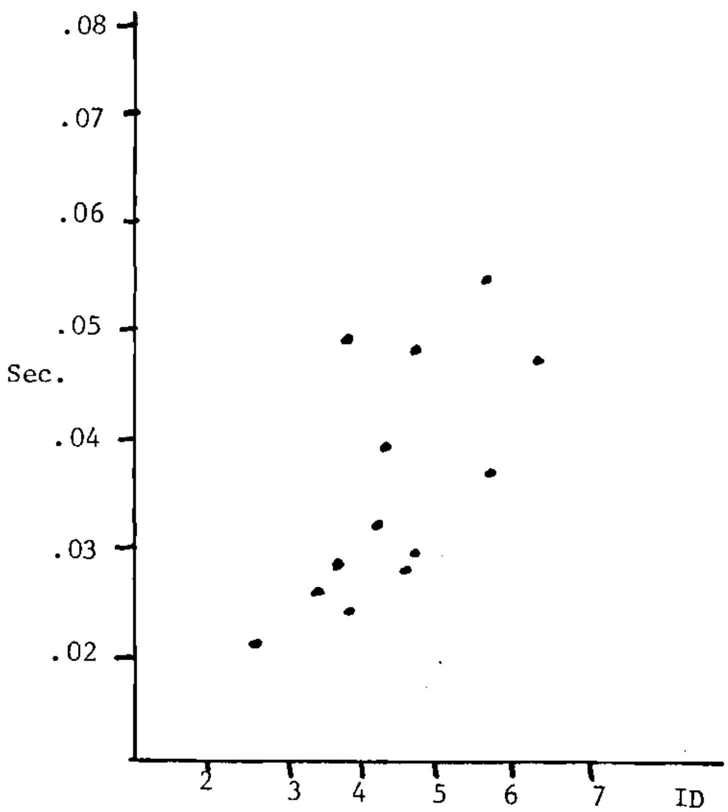


Figure F-20. Subject 4 Standard Deviation Motor Condition.

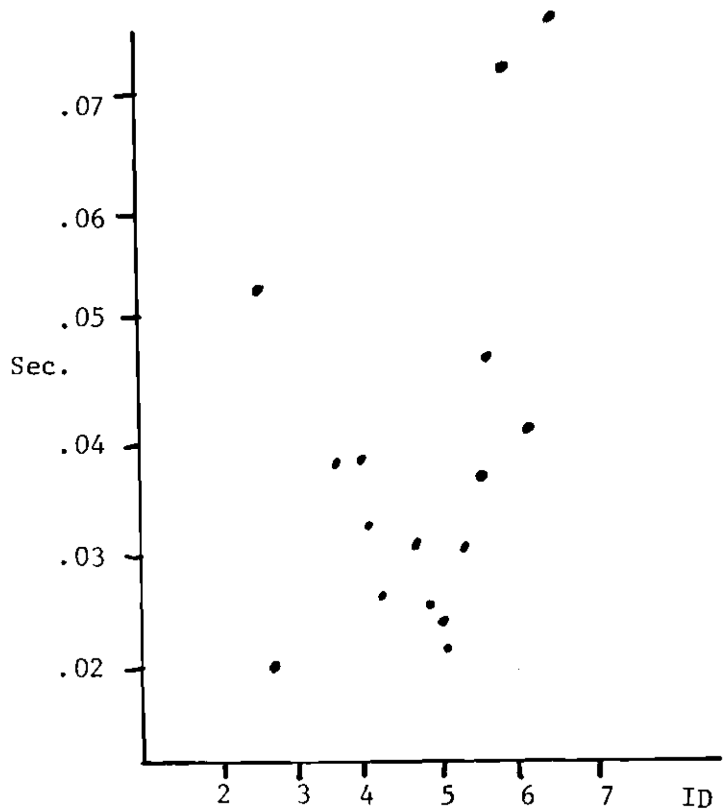


Figure F-21. Subject 1 Standard Deviation Mental Condition.

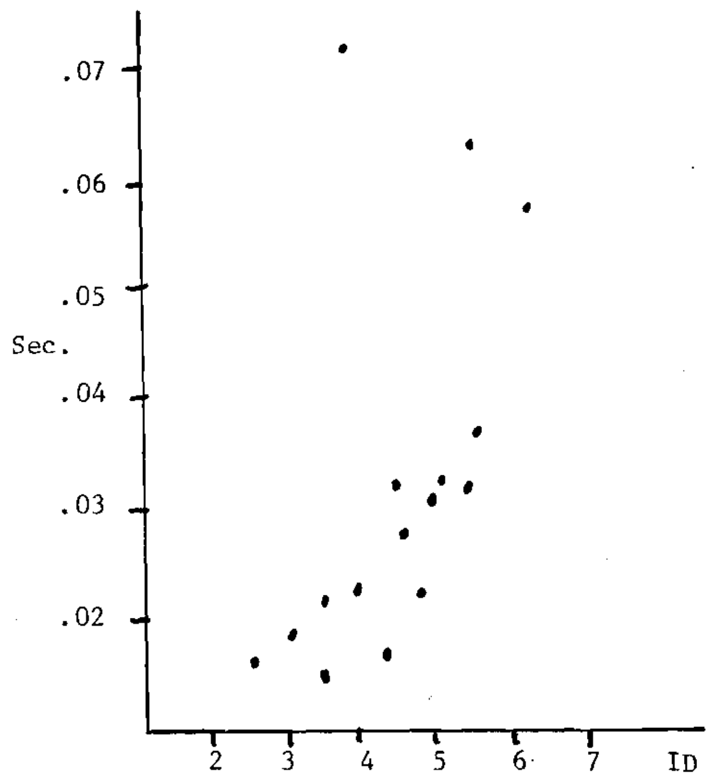


Figure F-22. Subject 2 Standard Deviation, Mental Condition.

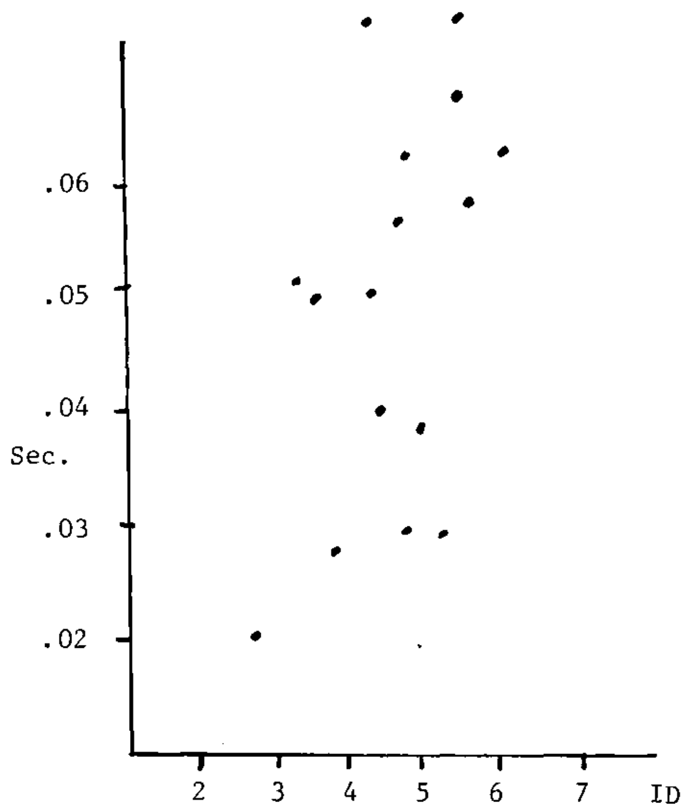


Figure F-23. Subject 3 Standard Deviation, Mental Condition.

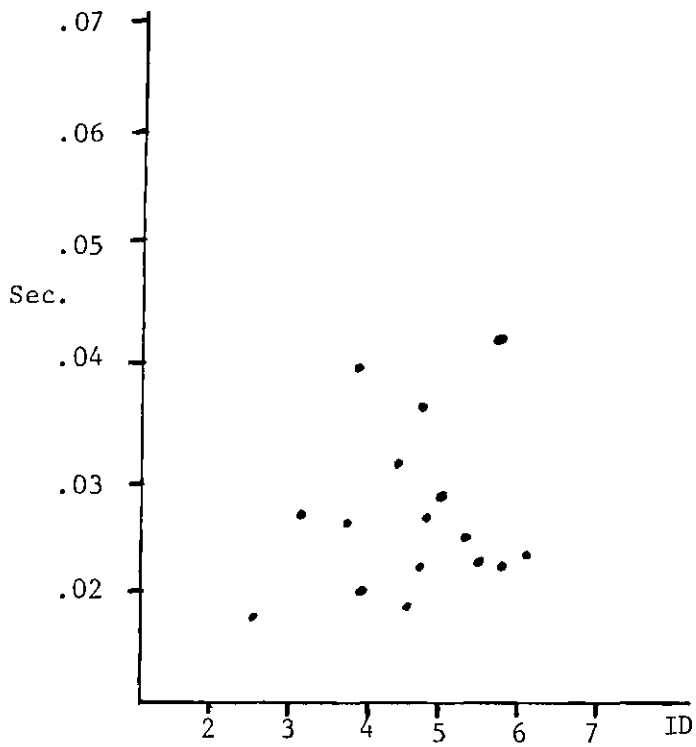


Figure F-24. Subject 4 Standard Deviation, Mental Condition.

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